CHAPTER 10: POWER SURGE: CHINA'S ELECTRIFICATION DRIVE AND PUSH FOR GLOBAL ENERGY DOMINANCE

Executive Summary

China's "electrification" strategy is increasing its influence in the global energy sector, which carries a number of risks for the United States. China's economy is rapidly electrifying, adding more hydro, nuclear, solar, and wind power generation in 2024 than Germany's annual total power consumption. Through massive state support and other forms of market distortions, China has become a dominant manufacturer of certain types of equipment at each stage of power generation and consumption. Building on decades of energy infrastructure construction abroad, China's role in global energy systems continues to expand through exports of low-carbon energy technologies and electricity grid components and investment in electric vehicle (EV) and battery factories abroad. The appeal of China's energy technology exports and investments is particularly strong in developing countries, where—aside from offering cheap solutions—China's technologies may mitigate developmental challenges like rural electrification in areas with weak grid infrastructure. The massive scale of China's production and investment across all stages of the electric power system has shifted the trajectory of global markets in a direction that benefits Chinese manufacturers.

The risks for the United States arising from China's expanding exports and investments include supply chain vulnerabilities—given high U.S. reliance on certain materials and products sourced from China—and cybersecurity threats to U.S. critical infrastructure. China supplies over half of the United States' imports of battery energy storage systems and low-voltage transformers, and it is a leading refiner of almost all the critical minerals necessary for the energy sector. Beijing began the process of weaponizing U.S. dependence on Chinese critical mineral refiners in July 2023 and could potentially use its manufacturing capacity in other critical products and materials as economic leverage. The extensive use of Chinese components in the U.S. power grid creates risks for cyber espionage and sabotage—which are significant in light of China's stated strategy and known activities like People's Republic of China (PRC)-sponsored Volt Typhoon's efforts to pre-position assets in U.S. critical infrastructure. Additionally, China's role in international energy systems expands its geostrategic influence, potentially giving it leverage over U.S. allies and partners or third countries that also depend on China for energy imports or even allow Chinese investment in their energy systems.

Key Findings

- China's government-supported dominance in key "new energy" sectors and growing footprint in global energy systems more generally raise numerous national security concerns for the United States and other countries. These risks include dependency on Chinese exports and technology, with associated leverage accruing to Beijing. Chinese components and systems also raise cybersecurity-related risks to critical infrastructure, which are acute in light of PRC malign efforts like Volt Typhoon.
- China's restrictions on critical mineral exports to the United States demonstrate its willingness and ability to leverage control of energy technology supply chains for economic coercion. Beijing could use similar tactics to undermine U.S. diplomatic objectives and negotiations with third countries. In 2025, firms across North America, Europe, and Asia faced mounting delays and demands for sensitive data during China's mineral export license reviews—turning supply chain chokepoints into instruments of coercion and corporate surveillance.
- China's burgeoning role in global energy systems is occurring through multiple channels: its firms are involved in the construction and operation of energy infrastructure globally, its components are embedded in power systems throughout the world, and its manufacturers are increasingly investing in overseas factories to boost market share abroad.
- China's national energy strategy has been focused on using government policy to grow "electrification" as a means of reducing its reliance on fossil fuel imports, boosting energy efficiency, and reducing pollution and carbon emissions. While it is still the world's leading consumer of fossil fuels, China has made significant progress toward its electrification goals, including by continuing to build coal-fired power plants.
- In light of global trends in favor of reduced carbon emissions, Beijing saw electrification as having benefits not only for its energy policy but also for its goals to become a global manufacturing superpower and grow its geostrategic power. China leveraged access to its market and its industrial policy toolset to become a dominant producer of key "new energy" technologies, including EVs, batteries, solar panels, and core wind turbine components. Its policies have already wiped out solar panel makers in the United States and EU, and similar dynamics threaten foreign producers of EVs, wind turbines, and other low-carbon technologies, undermining efforts to de-risk supply chains. China is also a major producer of key equipment used in energy storage, transmission, and distribution.

Introduction

In May 2023, U.S. cybersecurity agencies, allied and partnered agencies, and Microsoft announced that they had discovered a Chinese state-sponsored cyber actor—Volt Typhoon—targeting critical infrastructure in the United States. Since at least 2021, Volt Typhoon has infiltrated the U.S. power system, oil and gas pipelines, and other critical infrastructure. This cyber espionage allowed Volt Typhoon to collect operational insights into the electric grid, identify chokepoints with outsized control over grid operations, and pre-position cyber assets to potentially disrupt grid operations.

A disruption of a key power station or substation could have caused a national crisis on the scale of the power outage across Spain and Portugal in April 2025, which shut down their transportation, communication, water, grocery, and financial systems for 18 hours. While the Iberian outage was not caused by an adversarial actor, Chinese hackers' targeting of civilian infrastructure through groups like Volt Typhoon and Salt Typhoon make it important to understand the role China plays in U.S. and global energy markets, products, and infrastructure. China's "electrification" energy strategy has made it a dominant supplier of "new energy" technologies, and the Belt and Road Initiative has helped it grow its investments and influence in energy systems all over the world. This rapid scale-up has been driven by industrial policy—not market demand—and is generating overcapacity across electrification value chains, a dynamic that is distorting global markets and deepening dependency on Chinese supply. These developments create risks for the United States and its allies and partners around supply chains, cybersecurity, and Beijing's leverage and influence.*

China's Domestic Energy Strategy Increases Control of Key New Energy Sectors

China Is Rapidly Electrifying

China's domestic economy is rapidly electrifying, and China is now a global leader in manufacturing and installing many products and inputs used in electrification.† Electricity consumption growth in China has outstripped its real gross domestic product (GDP) growth since 2020 (see Figure 1).[1] Roughly half of that growth has been driven by manufacturing, with production of electric technologies like solar panels, batteries, and EVs accounting for over a third of industrial electricity demand growth.[2] In the first six months of 2023, China exported 114 gigawatts (GW) of solar panels, more than the total installed solar

*This chapter draws on the Commission's April 2025 hearing on "China's Domestic Energy Challenges and Its Growing Influence over International Energy Markets," consultations with experts, and open source research and analysis.

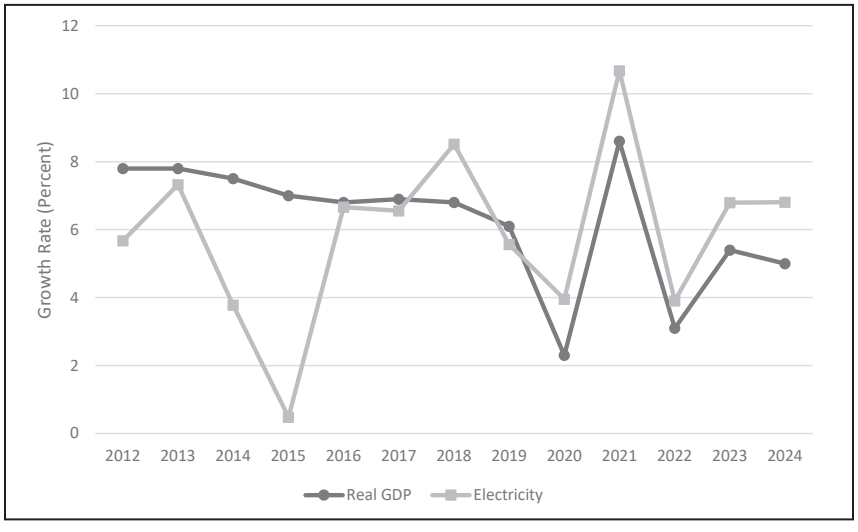
†Electrification is the expansion of electricity use in final energy consumption by converting energy-consuming devices, systems, and sectors from non-electric sources of energy to electricity. This can involve moving away from consumable, heat-based power sources like fossil fuels to non-consumable, electric technologies like solar, wind, and nuclear and can be incentivized by global environmental regulations and carbon taxation frameworks that penalize carbon-intense industrial processes. However, electrification does not require reducing fossil fuel use, and China demonstrates that a power system can generate most of its electricity from fossil fuels even as it promotes electrification. U.S. Department of Energy, *What Is Electrification?* accessed July 15, 2025; U.S. Energy Information Administration, *China*, May 19, 2025; Sam Boocker and David Wessel, "What Is a Carbon Border Adjustment Mechanism?" *Brookings Institution*, July 8, 2024.

capacity of the United States at that time, and China produced enough batteries in 2023 to meet all of global demand.[3]

Electricity consumption in China has also been driven by the widespread adoption of high-speed rail and electric passenger vehicles, trucks, and buses alongside an increased use of electric air conditioning and heating in homes and businesses.[4] Almost half the cars sold in China in 2024 were EVs, and there were more EVs sold in China alone in 2024 than were sold globally in 2022.[5] Data center power consumption has also contributed to China's electricity demand, more than doubling from 60–70 terawatt-hours (TWh) in 2019 to 166 TWh in 2024 and accounting for 1.7 percent of total electricity consumption.[6] Chinese data center power consumption is projected to rise to between 300 and 600 TWh by 2030, accounting for at most 4.6 percent of China's total electricity consumption.*[7]

To meet the growing demand for electricity, China has made massive power generation additions, and its power grid capital expenditures outpace its economic growth.[8] In 2024, China's new electric power generation from low-carbon sources alone (i.e., hydro, nuclear, solar, and wind) was greater than Germany's annual total power consumption.[9]

Figure 1: Real GDP and Electricity Growth Rates in China, 2012–2024



Source: Various.[10]

Beyond transforming China's domestic energy system, the massive scale of China's production across all stages of the electric pow-

*This projection of data centers' share of China's total electricity consumption is based on an S&P Global projection that China's total power consumption will exceed 13,000 TWh by 2030. While this projection may seem small compared to projections that data centers could consume up to 9 percent of U.S. electricity by 2030, the United States' four leading tech companies have outspent China's seven leading tech companies on capital expenditures by a factor of 8.5:1 over the last five years, suggesting that data center power demand in the United States will grow faster than in China. U.S. Department of Energy, *Clean Energy Resources to Meet Data Center Electricity Demand*, accessed August 26, 2025; Jeffrey Ding, "ChinAI #323: The AI Deflation of China's Tech Giants," *ChinAI Newsletter*, August 11, 2025; "Restructuring and Evolution: Key Drivers in China's Power Demand Surge," *S&P Global*, May 27, 2025.

er system has shifted the trajectory of global markets in a direction that benefits Chinese manufacturers (see Table 1). Fewer than one million EVs were sold annually around the world before 2017; in 2024, 17.3 million EVs were sold, 62 percent of which were Chinese-branded vehicles.[11] The China-led expansion of the global EV market reoriented upstream supply chains in favor of Chinese producers, with the lithium-ion battery market growing tenfold since 2016 and leading Chinese battery maker Contemporary Amperex Technology Co., Limited's (CATL) favored low-nickel lithium iron phosphate (LFP) chemistry winning out over alternative approaches from South Korean and Japanese rivals LG, SK On, and Panasonic.[12] Falling upstream prices and supply chain integration have driven Chinese EV prices lower, allowing Chinese manufacturers to price their EVs below competitors' in emerging markets.[13]

Table 1: China's Influence in Global Power Systems*

Stage of Power Production and Consumption	China's Leading Positions
Power Generation—Converting primary energy (e.g., heat, renewables) into electricity	China leads the world in installed capacity of renewable power generation, particularly solar, wind, and hydropower. It is also the dominant exporter of solar panels and wind turbine parts and is constructing a number of dams overseas. China leads the world in coal-fired power plant and nuclear reactor construction.
Storage—Storing generated power for future use (e.g., batteries)	China is the leading producer of lithium-ion batteries, including batteries used for energy storage by power stations and industrial end users.
Transmission—Sending electricity over long distances from generators to substations	China is a leading producer of many key components used for long-distance electricity transmission, including transformers, inverters, and rectifiers. It is also the dominant builder of ultra-high-voltage transmission lines used in a few countries.
Distribution—Sending electricity from substations to end users	In spite of its struggles with reliability in its own transmission and distribution system, China is a leading deployer of smart grid equipment and technologies as it tries to resolve physical barriers to grid modernization and use its electricity generation resources more efficiently.†
Consumption—Using electricity for residential, commercial, industrial, or transportation uses	China is the world's largest supplier of hybrid and fully electric vehicles and their batteries.

Source: Various.[14]

*For a more detailed discussion of the stages of electric power production and consumption, see Appendix I, "Electric Power Systems."

†In September 2025, China released the first plan implementing its "AI Plus" strategy—"AI Plus Energy." This plan lays out how Beijing plans to use artificial intelligence and related technologies to improve grid security and efficiency, particularly to better manage "fluctuating and intermittent" new energy sources. For more on China's AI Plus strategy, see "U.S.-China Tech Competition and Policy" in Chapter 1, "U.S.-China Economic and Trade Relations (Year in Review)." China's National Development and Reform Commission, "推进‘人工智能+’能源高质量发展的实施意见" [Implementing Opinions on Promoting the High-Quality Development of "AI Plus" Energy], September 4, 2025.

This pattern of upstream dominance and downstream price leadership reflects the same state-directed industrial overcapacity dynamics that experts warned in testimony could be used to crowd out global competitors and make foreign markets dependent on Chinese inputs.[15] Chinese policy support for other emerging energy technologies could further shape global energy developments. In 2021, China shifted support to research and development (R&D) and logistics infrastructure for hydrogen, a nascent industry both globally and in China, expanding its control of global green hydrogen production capacity (i.e., electrolyzers that produce hydrogen from water) from 8 percent in 2020 to almost 70 percent in 2024.[16] China now has the most annual hydrogen commercial vehicle sales and the largest market for hydrogen as an industrial and transportation fuel.[17]

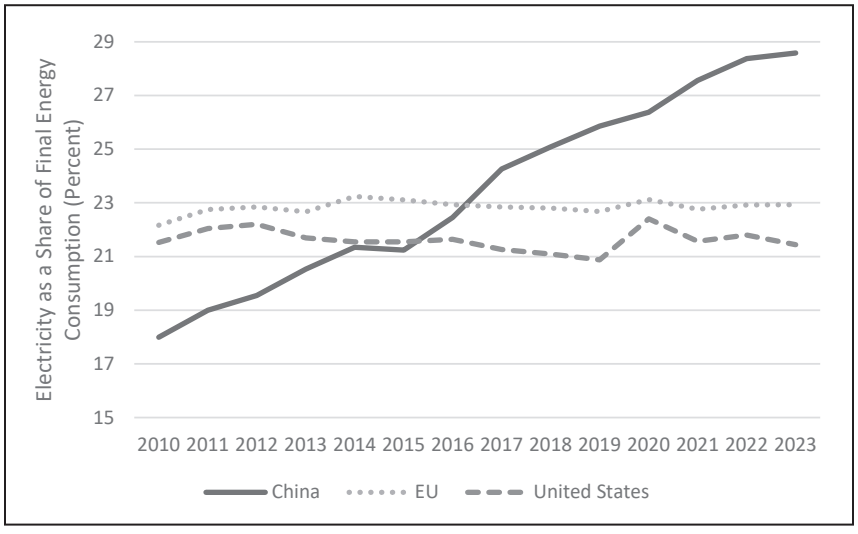
China's Domestic Energy Strategy Focuses on Electrification

Electrification is core to China's energy strategy.* In its 14th Five-Year Plan for a Modern Energy System, China aimed for electricity to make up 30 percent of final energy consumption by 2025.†[18] Now at 29 percent, electricity's share in China is higher than in the United States (21 percent) and the EU (23 percent), economies where electricity's share of final energy consumption has remained stable over the last 15 years (see Figure 2).[19] China's electrification strategy supports five overarching goals: energy security, energy efficiency, innovation and industrial upgrading, environmental improvement, and international influence.[20] As experts testifying before the Commission noted, over time, China's electrification strategy has resulted in geostrategic benefits, giving China global leverage in multiple segments of the electrification value chain, particularly for energy storage technologies.[21]

*For more on China's energy strategy, see U.S.-China Economic and Security Review Commission, Chapter 2, Section 3, "China's Energy Plans and Practices," in *2022 Annual Report to Congress*, November 2022, 234–290.

†China's five-year plans consist of an outline with hundreds of sub-plans. The 14th Five-Year Plan for a Modern Energy System was a sub-plan that fleshed out the energy objectives in the 14th Five-Year Plan Outline. China's National Energy Administration, "十四五" 现代能源体系规划 ["14th Five-Year Plan" for a Modern Energy System], accessed July 10, 2025, 1; Oliver Melton, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China ahead of the 13th Five-Year Plan: Competitiveness and Market Reform*, April 22, 2015, 3.

Figure 2: Electricity's Share of Final Energy Consumption in China, the EU, and the United States, 2010–2023



Note: Final energy consumption measures the energy sources directly consumed by end users as opposed to the unprocessed energy sources produced in or imported into a country. Most energy sources must be refined or transformed into products usable for consumption (e.g., crude oil refined into gasoline, coal burned to generate electricity). Some energy content is lost through those processes. Since electricity is often generated by burning fossil fuels and some initial energy content is lost between the production/import and final consumption stages, it is best to analyze electricity consumption as a share of final energy consumption. "China," *International Energy Agency*, accessed October 6, 2025.
Source: Various.[22]

Electrification Supports China's Energy Security Goals

China has long sought to increase its energy security by reducing reliance on imports. China is the world's largest consumer of fossil fuels and has remained focused on reducing dependence on seaborne fossil fuel imports vulnerable to a blockade, particularly oil and gas from the Middle East and Africa transiting the Malacca Strait.[23] However, natural gas and oil have grown as shares of China's energy supply, and China's import dependency on both oil and gas has risen since Xi Jinping became General Secretary of the Chinese Communist Party (CCP) in 2012 (see Figures 3 and 4).*[24]

Electrification helps China slow the growth of and ultimately reduce its dependence on imported oil and gas.† Electrification of transportation and residential heating—two of the top uses of oil and natural gas—decreases the amount of petroleum and gas consumed.[25] China's consumption of gasoline and diesel has already

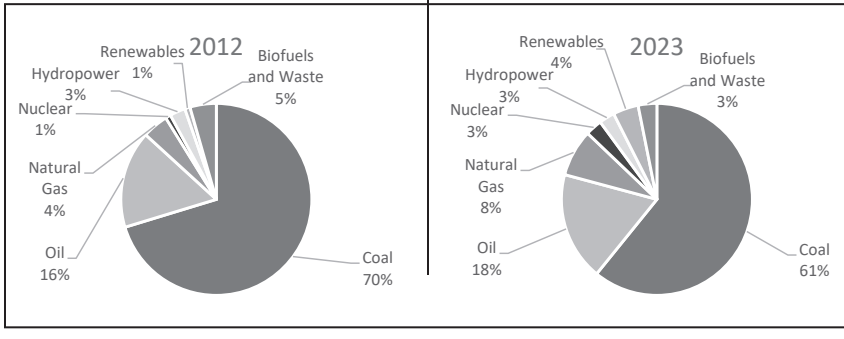
*China began importing pipeline gas from Russia and Central Asia in 2010, so 40 percent of China's natural gas is now imported over land. Energy Institute, "2025 Statistical Review of World Energy—*Gas: Inter-Regional Trade (from 2000)*," July 3, 2025.

†In 2024, 55 percent of China's electricity was generated by coal power and 36 percent by hydro, solar, nuclear, and wind power. Only 2 percent was generated by natural gas, and almost none was generated by oil. Although China imports some coal for cost reasons, it does not depend on coal imports because it has enough domestic coal production to meet its coal consumption. U.S. Energy Information Administration, *China*, May 19, 2025; David Fishman, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Domestic Energy Challenges and Its Growing Influence over International Energy Markets*, April 24, 2025, 8–9.

likely peaked due to increased EV use.[26] In the future, electrification of industrial sectors that are major users of oil and natural gas could also decrease the amount of imported energy consumed.[27] For example, in the steel industry, multiple Chinese producers are investing in low-carbon steel production, including electric arc furnaces, and provincial governments permitted only electric steelmaking projects in H1 2024.[28] This shift toward electricity as the energy source for industrial production reduces China's exposure to maritime chokepoints like the Malacca Strait but also strengthens its ability to weather future energy sanctions or supply disruptions in a geopolitical crisis.

Notably, electrification does not necessarily mean using fewer fossil fuels. While China is increasing the percentage of its energy needs that come from renewables, it is also expanding its capability to convert coal into electricity to improve its energy security, given its large coal reserves.[29] China's continued buildout of coal-fired power plants alongside renewables—despite an average coal plant utilization rate of 55 percent—demonstrates how China is pursuing energy security by increasing the supply of electricity, whether generated by coal or renewables.[30]

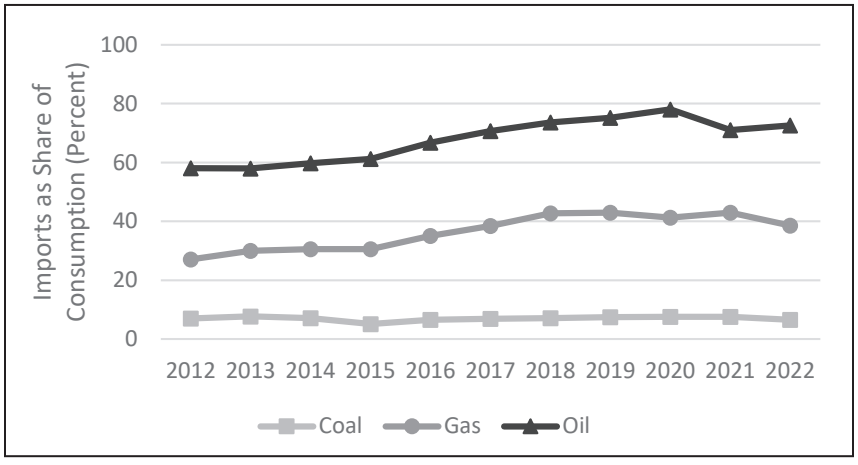
Figure 3: China's Total Energy Supply, 2012 vs. 2023



Note: When the Commission last examined the change in China's energy mix over time in its *2022 Annual Report to Congress*, it used data from BP's "Statistical Review of World Energy." In 2025, the Energy Institute updated the methodology of the "Statistical Review" to align with other organizations, including the International Energy Agency, because the previous methodology calculated how much fossil fuel energy was displaced by renewables, not the amount of energy renewables supplied. For a historically consistent dataset, the Commission's 2025 Annual Report is using data from the International Energy Agency. "About the Statistical Review," *Energy Institute*, accessed July 18, 2025.

Source: "Evolution of Total Energy Supply in China since 2000," *International Energy Agency*, accessed July 18, 2025.

Figure 4: China's Fossil Fuel Import Dependencies as a Share of Total Consumption, 2012–2022



Source: Various.[31]

Electrification Drives Energy Efficiency

Electrification could help China expand its manufacturing base and boost exports by reducing costs. Among other benefits, consuming electricity rather than heat-based sources for production can reduce input costs in manufacturing.[32] As China's labor costs have risen, energy efficiency could help offset cost pressures and preserve its global price competitiveness.[33] China succeeded in reducing the energy intensity of its economy by roughly 15 percent from 2015 to 2020.[34] That effort has since stalled, however, falling only 2 percent from 2020 to 2023 as energy consumption growth outpaces GDP growth partly because China's economic growth has relied more on energy-intensive industrial sectors following COVID-19.[35] China will likely miss its 2025 energy intensity reduction target of 13.5 percent.*[36] Nevertheless, by electrifying production and driving down the cost of low-carbon energy inputs, China is positioning itself to remain dominant in global manufacturing even as markets shift toward decarbonization.[37]

China has invested in modernizing its coal-fired power plants and lower-emissions steel production in an attempt to hit energy efficiency targets while retaining industrial capacity. New coal plants in China burn at least 45 percent less coal per kilowatt-hour (kWh) than the average U.S. plant.[38] In 2022, Chinese industrial and environmental regulators set a goal of at least 15 percent of steel production using electric arc furnaces by 2025, though the target had not been reached when China suspended permitting for new facilities in mid-2024 to address overcapacity concerns.[39] Nonetheless, China's emissions from steel production have declined steadily

*China redefined "energy intensity" in February 2024 to make it easier to meet its target by excluding renewable and nuclear energy from its energy intensity data. This will also make it difficult to compare China's energy intensity going forward to historical or global statistics. Lauri Myllyvirta, "How China Completely Redefined a Key Energy Target," *Dialogue Earth*, March 19, 2024.

as the government has forced industry consolidation toward larger firms with cleaner operations.[40] China claims that these modernizations not only improve efficiency but also make its industrial supply chains "clean" or "green," potentially reinforcing their appeal to international buyers and embedding Chinese firms in the future of low-carbon manufacturing.[41]

China's Focus on Electrification Supports Its Industrial Policy

Electrification goals dovetail with China's technology ambitions. Industrial policies dating back to the mid-1990s have sought to position China as a dominant innovator, producer, and exporter of low-carbon technologies, particularly technologies Chinese government officials dubbed in 2023 the "new three" export industries: EVs, solar, and batteries.[42] China's breakout success in EVs fulfills a vision articulated in the 2006 National Medium- and Long-Term Program for Science and Technology Development and repeated in Made in China 2025, which aimed to leapfrog U.S., German, and Japanese automakers dominant in internal combustion engine vehicles.[43] China met its Made in China 2025 target for three million new energy vehicle sales four years early, in 2021, and its target for 1,200 GW of solar and wind generation capacity six years early, in 2024.*[44]

China continues to incentivize innovation in energy technologies, with government-supported "national demonstration projects" that include solar thermal, geothermal, hydrogen-fed steel production, and energy-saving manufacturing processes.[45] Through these parallel efforts, China has cemented a global lead across certain electrification value chains, enabling it to set de facto standards in the industry and shape the future of energy competition in ways favorable to Beijing.[46]

Electrification Supports China's Environmental Goals

China's energy strategy is tied to its environmental goals. With many cities plagued by smog from surrounding factories and power plants, reducing air pollution has become a quality of life imperative for the CCP. Xi Jinping has championed the concept of an "ecological civilization"—conserving resources, curbing pollution, and balancing environmental concerns with economic growth—adding it to the Party's constitution in 2012.[47]

Electrification can help reduce pollution emissions when it enables low-carbon power generation to displace coal consumption as industry shifts from heat-based (like coal-fired steel production) to electricity-based processes (like electric arc steel furnaces).[48] Electrification's impact on pollution may be muted in China, since its reliance on coal for electricity generation means that its electricity is more carbon intense—and thus more pollution intense†—than

*For more on China's progress toward its Made in China 2025 targets, see Daniel Blaugher, Benton Gordon, and Matthew Dagher-Margosian, "Made in China 2025: Evaluating China's Performance," *U.S.-China Economic and Security Review Commission*, November 2025.

†Some major pollutants are closely linked to industrial activity and fossil fuel combustion, so reducing fossil fuel consumption or burning fossil fuels in cleaner and more efficient ways can reduce pollution levels. Chengcheng Qiu, "China's Air Pollution Shifts West: Industrial Relocation Outpaces Clean Energy Transition—China Q1 2025 Air Quality Briefing," *Centre for Research on Energy and Clean Air*, June 4, 2025, 4; U.S. Energy Information Administration, *Coal Explained: Coal and the Environment*, April 17, 2024.

the global average.[49] That could change, however, as David Fishman, principal at the Lantau Group, testified before the Commission that China's most advanced coal plants are significantly more efficient than previous generations and due to their role in backup and load-smoothing for renewables can "[make] just as much of a contribution to trimming emissions as replacing coal with renewable power."*[50] Average air quality in China has generally improved under Xi but remains below the World Health Organization and China's own air quality standards, and it continues to worsen in more heavily industrialized northeastern, southern, and western China.[51] While pollution control remains a domestic priority, the CCP also uses environmental policy as a strategic narrative—branding Chinese energy technologies as "green" for export markets, even as lifecycle emissions and embedded supply chain risks often tell a different story.[52]

China's emissions targets have similarly achieved mixed results amid conflicting incentives and priorities. In 2021 as part of the 14th Five-Year Plan, China shifted its focus from pollution to climate goals and energy transition.[53] China's total carbon dioxide emissions began falling in March 2024.[54] In the first half of 2025, they fell 1 percent year-over-year, largely due to increases in solar, wind, and nuclear electricity generation outpacing growth in electricity demand for the first time and moderate improvement in coal-fired power plant efficiency.[55] As with pollutants, while China's overall emissions have begun falling, its industrial emissions continue to rise.[56]

It is unclear if this decline represents peak emissions or a temporary plateau. In the first half of 2025, China's solar installations more than doubled year-over-year as developers rushed to take advantage of expiring subsidies, with more installations in May alone than the United States installed in 2023 and 2024 combined.[57] In September 2025, Xi announced China's new Nationally Determined Contribution for 2035 under the Paris Agreement, including commitments to lower greenhouse gas emissions by 7 to 10 percent below peak levels, for non-fossil fuel energy consumption to make up at least 30 percent of total energy consumption, and to increase wind and solar power capacity by six times over 2020 levels.†[58] While this suggests a continued decline in emissions, solar and wind power was increasingly rejected from the power grid in the first half of 2025, and some planned renewable energy projects were canceled.‡[59]

*These "ultra-supercritical" coal plants use high-efficiency boilers to get more energy out of the same amount of coal, reducing emissions. Additionally, they can ramp output up or down within hours, enabling them to serve as flexible backup and load-smoothing assets in China's electricity system. In most other economies, natural gas plants fulfill this function, facilitating renewable integration while ensuring energy demand continues to be met. David Fishman, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Domestic Energy Challenges and Its Growing Influence over International Energy Markets*, April 24, 2025, 89–90; David Fishman, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Domestic Energy Challenges and Its Growing Influence over International Energy Markets*, April 24, 2025, 17.

†These commitments are significantly lower than those of other countries. For example, Brazil committed to reducing emissions by at least 59 percent, and the EU is planning at least a 66 percent reduction by 2035. Valerie Volcovici and Yukun Zhang, "China Leads Nations with New Climate Plans, Defying U.S. Climate Denial," *Reuters*, September 25, 2025.

‡In power generation, "rejected" renewable energy refers to curtailment, or the deliberate reduction of a generation resource'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,

Moreover, long-run trends continue to favor coal, including long-term coal power purchase agreements and mandates for baseload coal generation.[60] Over 80 percent of global coal-fired power plants under construction are based in China—despite the average coal plant in China having a below-global-average 55 percent utilization rate.[61] China has also weakened incentives to integrate renewable power onto electrical grids.[62] Taken together, these contradictions suggest that China's climate commitments—while outwardly ambitious—remain tightly coupled to industrial policy, fossil fuel entrenchment, and a desire to preserve strategic flexibility rather than drive deep decarbonization.

China Seeks to Expand International Influence through Electrification

China seeks to position itself as a leader in renewable energy, gain strategic access to global energy resources, and grow its geopolitical influence. For at least 30 years, over 190 countries have become parties to international agreements committing to reducing greenhouse gas emissions.[63] By establishing itself as a leader in electrification and renewables, China gains two types of international benefits.

First, China seeks to enhance its reputation among countries for helping to address risks from climate change. This is an important messaging strategy in China's diplomacy, as China is the world's largest annual emitter of greenhouse gases, has emitted more carbon historically than the entire EU, and has accounted for 90 percent of global growth in carbon emissions since it signed the Paris Agreement in 2015.[64]

Second, foreseeing the growth in demand for renewable energy production, China invested heavily in developing manufacturing capacity in these sectors both to expand its manufacturing sector in an area of global growth and to increase its global leverage in an area in which many countries would have demands.[65] As will be discussed below, China's significant subsidies and other policy support resulted in a leading role in key low-carbon energy sectors. In addition, the energy sector has accounted for almost 40 percent of China's Belt and Road Initiative (BRI) loans and investments by value.[66] These projects often serve strategic aims, with the highest concentration of BRI energy infrastructure investments in Central Asia and the Middle East coinciding with efforts to increase cooperation to secure oil and gas supplies.[67] BRI energy projects—described further in "China Continues BRI Investments in Overseas Energy Generation Infrastructure" later in this chapter—also give China a foothold in global energy supply chains and allow Chinese firms to install digital control and data collection systems in energy systems around the world.[68]

Chinese policy indicates China has a long-term strategy of encouraging participation in international standards-setting organizations to influence standards development and leverage market

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including weather patterns such as peaking sunlight during midday or strong winds during a storm. Curtailment also results from local grid companies choosing not to purchase renewable energy from local generators due to existing contracts or a preference for energy generated from coal. "China's Record Renewables Buildout Is Wasting Power as Grid Lags," *Bloomberg*, August 4, 2025; Anders Hove, "Trends and Contradictions in China's Renewable Energy Policy," *Columbia University Center on Global Energy Policy*, August 28, 2020; "Impacts of Renewable Energy on Grid Operations," *California Independent System Operator*, May 2017.

share to set de facto standards. In its 14th Five-Year Plan for a Modern Energy System, China aims to "actively participate in setting international energy standards and speed up the international integration of China's energy technology and standards."[69] Experts have previously testified before the Commission that China believes there are both market and geostrategic advantages from promoting international standards.[70] Successful promotion of standards developed by Chinese firms can create lock-in effects, making it costly to switch suppliers, particularly for infrastructure like telecommunications and grid equipment.[71] Under these efforts, China's leadership roles in technical committees within multiple standards-setting organizations have increased rapidly in the past 15 years and now rival those of major advanced economies.[72] China holds a number of leadership positions in technical committees and subcommittees within the International Electrotechnical Commission (IEC), a global standards-setting body headquartered in Europe that develops standards for all electrical technologies. These include technical committees and subcommittees on power electronics for transmission and distribution systems, nuclear instrumentation, and electrically powered transport devices (e.g., charging stations, unmanned delivery vehicles).[73] China has also pushed for the creation of new technical committees in fields it dominates, like ultra-high-voltage transmission lines.[74] China's State Grid and other state-owned entities have also initiated a number of standards adopted by the International Organization for Standardization (ISO), the IEC, and the Institute of Electrical and Electronics Engineers (IEEE) Standards Association, including standards related to "smart energy" control and management.[75]

Collectively, China now has a variety of levers to exert influence over global energy systems, including a dominant role in manufacturing certain energy technologies and equipment, the capacity to influence technical standards through standards development organizations, the market share to set de facto standards for some technologies, and multiple tools to affect energy infrastructure investment, construction, and operation around the world.

China's Hydropower Buildout Harms Tibetans and Creates Geopolitical Leverage

Although China regularly experiences droughts and is demolishing hydropower dams in other parts of the country to protect fisheries and increase downstream water flow, it continues to invest in dams that harm communities in Tibet and increase its control over South and Southeast Asian water flows, giving it geopolitical leverage and threatening downstream ecologies, fisheries, and agriculture.[76]

Since 2000, China has built 54 dams across six rivers in Tibet, with another 66 under construction or in preparatory stages and 73 more planned.[77] These dams exacerbate the risk of earthquakes, landslides, and mudflows; create flood risks if damaged by earthquakes; and relocate hundreds of thousands of Tibetans while destroying their villages and religious sites.[78] In July 2025, China began construction on the Motuo Hydropower Station in

China's Hydropower Buildout Harms Tibetans and Creates Geopolitical Leverage—*Continued*

Tibet, located on the Yarlung Tsangpo, also known as the Brahmaputra River in India.[79] At $168 billion for 300 TWh of annual electricity production, it is expected to be the world's largest hydropower dam, almost five times the cost and producing over three times the electricity of the Three Gorges Dam.[80] Due to relatively lower energy needs in Tibet and existing energy surpluses in neighboring Sichuan and Yunnan Provinces, the project will also require a $7 billion ultra-high-voltage transmission line to export its energy to Guangdong, Hong Kong, and Macau.[81] Tibetans have protested against dam construction, and in response the Chinese government has detained hundreds of protesters (injuring some), increased surveillance of Tibetans, and enforced a communications blackout, preventing Tibetans in areas where protests occurred from communicating with the outside world.[82]

China's domestic dam construction impacts the ecosystems of Tibet and those of countries with rivers that originate in Tibet, particularly the Mekong River in Southeast Asia and the Brahmaputra River in South Asia. Over half of the dams on the main branch of the Mekong are in China.[83] Nineteen percent of fish species in the Mekong—a major global fishery—are heading toward extinction due to hydropower development, and Chinese-built dams have blocked nutrient-rich sediment from reaching tens of thousands of farms, reducing arable land in Vietnam's Mekong River Delta.[84] Dams on the Brahmaputra also restrict water flow and prevent nutrient-rich sediment from traveling downstream to India and Bangladesh.[85] The Motuo Hydropower Station will not have a large reservoir but will divert a portion of the river's water through four tunnels to a downstream portion of the river, reducing water flow in an ecologically diverse part of the river.[86]

China's hydropower expansion could also enable it to manipulate water flows in downriver countries, providing a coercive tool to disrupt vital water resources and related energy generation in neighboring states.[87] As roughly one-third of India's water comes from Tibet, Indian officials are concerned the Motuo dam could enable China to unexpectedly release water flows and flood parts of northeastern India.*[88] India is expressing its opposition to Chinese dams by building its own dams near its de facto border with China.[89]

China's Overlapping Energy and Industrial Strategies Create Overcapacity and Global Dependence on China

China's long-term industrial policies, especially direct grants, subsidies, and demand-side incentives, have led to overcapacity and the dumping of underpriced energy products on global markets (see Ta-

*On the Brahmaputra River, where China's Motuo Hydropower Station is being constructed, Tibet accounts for 25 percent of India's water. Combined with the dam's reservoir-free design, this limits China's ability to reduce or increase India's water supply because most of the Brahmaputra's flow comes from monsoon rains in India. Amber Zhang, "Why China Is Building the World's Largest Hydropower Station in Tibet," *Baiguan*, July 30, 2025.

ble 2). (For more on how Chinese industrial policy created overcapacity in a variety of industries, see Chapter 8, "China Shock 2.0.") Rhodium Group found that from 2015 to 2023, direct grants to power generation, battery, and EV firms grew faster than those to any other sector, and the Kiel Institute found that, especially for low-carbon energy industries, China's subsidies were three to nine times greater than OECD countries'.[90] Demand-side incentives included exempting new energy vehicles from certain taxes, providing rebates and subsidies for EV purchases, fast-tracking vehicle registrations, and directing local governments to buy fleets of electric buses, electric taxis, and supporting charging infrastructure.[91]

These policies incentivized multiple firms to enter new industries, and as unsustainable numbers of firms competed on innovation, scale, and supply chain integration, continued subsidies enabled companies to invest in more capacity than the market demanded and to sustain unprofitable competition on price.[92] For example, subsidy-fueled solar panel manufacturing capacity in China is now twice global market demand, and China's seven publicly listed solar panel manufacturers reported an aggregate net loss in 2024.[93] This overcapacity also accelerates price collapses across global low-carbon technology sectors—displacing international competitors and reducing incentives for alternative suppliers to scale, even as losses mount inside China.[94]

Table 2: Chinese Overcapacity and Dumping in Global Energy Markets, 2023*

Technology	China's Global Production Share (by quantity)†	China's Share of Global Production Capacity	Overcapacity, Dumping, and Other Concerns
Batteries	Components: 92 percent of anodes 81 percent of cathodes 77 percent of cells Finished Products: 65 percent of EV batteries	84 percent (2.5 times global demand)	In May and July 2025, the U.S. Department of Commerce announced preliminary affirmative determinations in anti-dumping and countervailing duty (AD/CVD) investigations of active anode material from China, with final determinations to be announced in December 2025. Government subsidies to CATL and other battery makers continue to rise. Since August 2025, the U.S. Forced Labor Enforcement Task Force has prioritized enforcing presumptive prohibitions on importing lithium, a key battery input, from Xinjiang.

*All data are from 2023 except where noted.
†This represents the share of production located in China, including foreign-branded products made in China. Battery component quantities are measured in gigawatt-hours, EV and EV battery quantities are measured in units, and green hydrogen, solar panel, and wind turbine quantities are measured in gigawatts.

Table 2: Chinese Overcapacity and Dumping in Global Energy Markets, 2023—*Continued*

Technology	China's Global Production Share (by quantity)*	China's Share of Global Production Capacity	Overcapacity, Dumping, and Other Concerns
Electric Vehicles	72 percent (2024)	Data not available	In October 2024, the European Commission imposed countervailing duties on battery EVs from China. While China phased out an EV consumer rebate, China has increased spending on the sales tax exemption and introduced a trade-in subsidy for EVs.
Green Hydrogen	Components: 71 percent of electrolyzers	59 percent (six times global demand)	In September 2024, the EU imposed limits on the amount of Chinese content in hydrogen grant recipients' projects.
Solar Panels	Components: 92 percent of polysilicon 97 percent of wafers 89 percent of cells Finished Products: 83 percent of modules	82 percent (two times global demand)	In September 2024, the U.S. International Trade Commission maintained AD/CVD orders on solar cells and modules from China that were imposed in 2012. Since June 2022, the U.S. Forced Labor Enforcement Task Force has prioritized enforcing presumptive prohibitions on importing polysilicon, a key solar panel input, from Xinjiang.
Wind Turbines	Components: 66 percent of blades 71 percent of nacelles	64 percent (2022)	In October 2024, the U.S. International Trade Commission maintained AD/CVD orders on utility-scale wind towers from China that were initially issued in February 2013.

Note: The United States has also imposed Section 301 tariffs on Chinese batteries, EVs, and solar components in response to China's unreasonable and discriminatory technology transfer, intellectual property, and innovation policies. U.S. Trade Representative, "Notice of Modification: China's Acts, Policies and Practices Related to Technology Transfer, Intellectual Property and Innovation," 89 Fed. Reg. 76581–76614 (September 18, 2024).
Source: Various.[95]

China's central government has publicly called for companies to address overcapacity in the solar and auto sectors, but these exhortations have been largely ineffective as conflicting incentives perpetuate dynamics that have oversaturated China's domestic market. Since 2024, a common pattern has played out with central government agencies pressuring firms to cut production and new investment. Firms have at best made and broken promises, with a number

*This represents the share of production located in China, including foreign-branded products made in China. Battery component quantities are measured in gigawatt-hours, EV and EV battery quantities are measured in units, and green hydrogen, solar panel, and wind turbine quantities are measured in gigawatts.

of solar firms reneging on agreements to reduce production, observe a price floor, and delay new factory investments.[96] EV maker BYD earned a public rebuke from regulators after cutting prices to razor-thin margins to sell down excess inventory.[97] After a growing chorus of criticism by Chinese regulators for excessive price cutting, as well as an August 2025 statement from Xi urging provincial governments to diversify support away from EVs and a small group of industries, a group of Chinese agencies issued measures intended to address excessive competition on price.*[98]

Aside from facing a prisoner's dilemma of not wanting to lose market share from reducing capacity or maintaining higher prices, firms also face pressure from local governments to maintain operations in their jurisdiction, boosting local GDP. Such pressures likely explain state-owned Chang'an Automobile and Dongfeng calling off a merger aimed at consolidating operations even though both operate at less than half capacity.[99] This tension between central directives and local growth mandates underscores a structural contradiction at the heart of China's industrial policy: firms are politically incentivized to expand capacity, even when doing so undermines long-term market stability and global trust in Chinese supply chains.[100]

Chinese companies' overcapacity has increasingly created global dependence on Chinese production in "new energy" sectors, in part by driving out foreign competition. Before 2005, Chinese solar firms controlled hardly any global market share, but a central government push to support strategic emerging industries led local governments to tell banks to direct more lending toward solar firms and even ask other industries to give up land without compensation to support the construction of new solar panel factories.[101] In 2011, by which point Chinese firms held almost 60 percent of global solar production capacity, three major U.S. solar firms announced bankruptcies after being undercut by Chinese competitors with access to cheap loans from state-owned banks, low-cost electricity, low-cost or free land from local governments, tax breaks, and low-cost labor.[102] Chinese companies then acquired bankrupt U.S. solar and battery rivals and transferred their intellectual property (IP) and production to China.[103]

China's photovoltaic cell production is concentrated in Xinjiang, from which between one-third and one-half of the world's polysilicon used in solar panels is sourced, as well as where abundant cheap coal in part reduces production costs.[104] In June 2021, the U.S. Department of Labor announced Chinese polysilicon as its first-ever out-of-cycle addition to a list of goods produced with suspected forced labor, and U.S. Customs and Border Protection issued a withhold release order on polysilicon from Xinjiang-based manufacturer Hoshine Silicon Industry Co. Ltd. due to concerns it was produced

*In September 2025, four Chinese agencies jointly announced that licenses would be required for battery EV exports starting in January 2026. Internal combustion engine and hybrid vehicles are already subject to these requirements, indicating that this is a response to low-quality EV exports, not an export control regime like those imposed on critical minerals. For more on export controls, see "China's Dominance in Energy-Related Critical Mineral Refining Creates Supply Chain Vulnerabilities" later in this chapter. China's Ministry of Commerce, 公布对纯电动乘用车实施出口许可证管理 [Announcement Regarding the Management of Battery Electric Passenger Vehicles Export License Implementation], September 26, 2025; "China to Require EV Export Permits to Safeguard Chinese Brand Image Overseas," *Reuters*, September 26, 2025.

with forced labor.* [105] The Department of Homeland Security also included silica-based products, including polysilicon, in its list of high-priority enforcement items for its strategy to implement the Uyghur Forced Labor Prevention Act.† [106]

Chinese wind turbine firms have also caused European wind turbine manufacturer Siemens Gamesa to pull back from African and Latin American markets by undercutting the competition with low pricing not supported by market fundamentals.[107] China's price competition further extends to upstream supply chains like raw materials and processed metals.[108] Due to these government subsidies and aggressive pricing strategies, Chinese firms now play a leading role across the upstream and downstream segments of many new energy technology supply chains, and the world is increasingly dependent on China to provide new energy solutions.[109] This dependency—built through industrial policy, strategic acquisitions, and systematic price undercutting—gives Beijing long-term leverage over the clean energy transition in both developed and developing economies.

China's International Energy Footprint Is Growing

China is transforming the future of energy production and consumption beyond its borders through a number of channels, including: increasing exports of new energy technologies, ramping up production and exports of critical minerals as new energy inputs, expanding global greenfield investment to manufacture new energy products, and funding BRI projects in new energy generation infrastructure. Given the current market direction, the world is set to become more dependent on China for these new energy products and related inputs. While many of these trends are focused on global responses to risks from climate change, China's dominance of these sectors comes with risks of its own, including dependency and vulnerability in critical infrastructure.

China Dominates in New Energy Product Exports

As discussed above, China's supply-side industrial policy distortion and export-driven economic model have driven surges in exports of new energy products (see Figure 5). In 2024, Chinese firms exported $182.2 billion of low-carbon energy technologies, including $66 billion of solar panels, $61.7 billion of lithium battery technologies, $47.8 billion of EVs, and $6.4 billion of wind turbines.[110] China's rapid export surges are most evident in its EVs and lithium batteries, which rose 1,500 percent and 287 percent in trade value, respectively, from 2020 to 2024.‡ [111] The trade value of solar panel

*On the same day, the U.S. Department of Commerce's Bureau of Industry and Security added several polysilicon producers to the Entity List for their connection to forced labor in China. Since at least 2017, the Chinese government has been using forced labor of tens of thousands of Uyghurs and other ethnic and religious minority groups in detention centers in Xinjiang. Other products from Xinjiang, including cotton and tomatoes, were previously subject to withhold release orders. U.S. Department of Commerce, Bureau of Industry and Security, "Addition of Certain Entities to the Entity List," 86 Fed. Reg. 33119–33122 (June 24, 2021); U.S. Department of Labor, *Shining a Light on Exploitation in the Solar Supply Chain*.

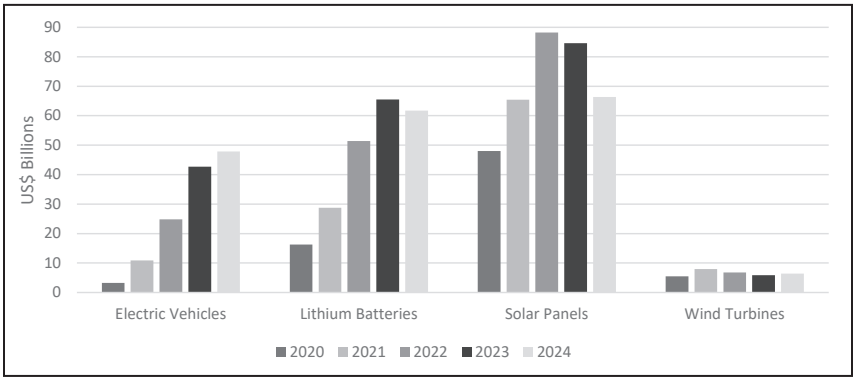
†The Uyghur Forced Labor Prevention Act (Pub. L. No. 117-78) went into effect in June 2022 and prohibits imports of items from Xinjiang unless the importer can provide clear and convincing evidence they were not produced with forced labor.

‡The surge in export value was not a product of price increase. EVs and lithium batteries' trade volume also rose 920 percent and 70 percent, respectively, from 2020 to 2024.

exports, on the other hand, may appear to be decreasing, but falling prices disguise a 3 percent increase in export volume in gigawatts in December 2024 from the previous year.* [112]

The export surges in new energy products resulted from China's growing overcapacity in these sectors in recent years. As discussed earlier, Chinese industrial policies encouraged firms to enter new energy sectors while providing sustained investment and subsidies, which fueled overcapacity and unprofitable price competition far beyond domestic demand. To stay in business, loss-making firms have turned to exports, seeking higher profit margins on their new energy products than they earn from domestic sales. For example, BYD sells the Atto 3, a compact EV, in Germany for more than twice the price it charges in China and remains competitive in the German market.[113] In effect, Chinese firms are exporting the economic consequences of overcapacity—propping up domestic sectors by seeking profitability abroad while distorting international markets in the process.

Figure 5: China's Exports of New Energy Products, 2020–2024



Source: UN Comtrade and China's General Administration of Customs.[114]

Developing countries are absorbing China's export surges of low-carbon energy technologies. For example, China's exports of EVs to emerging markets such as Southeast Asia and Latin America overtook those to Europe in 2024.[115] China has positioned its energy approach as a more efficient, cheaper, and "greener" alternative to carbon-intensive energy products. Some countries welcome China's low-cost new energy products to replace their unreliable, expensive grid infrastructure.[116] For China, this increase in demand worldwide serves as an opportunity to expand its reach into new markets and lock in its products in other countries' energy infrastructure. For instance, with an energy grid made costly and unreliable by earlier Chinese infrastructure investments, Pakistan recently turned to Chinese new energy solutions, becoming the third-largest importer of China's solar panels.† This example illustrates how China ap-

*Solar panel product codes have different units, such as kilograms and number of items, and cannot be aggregated.

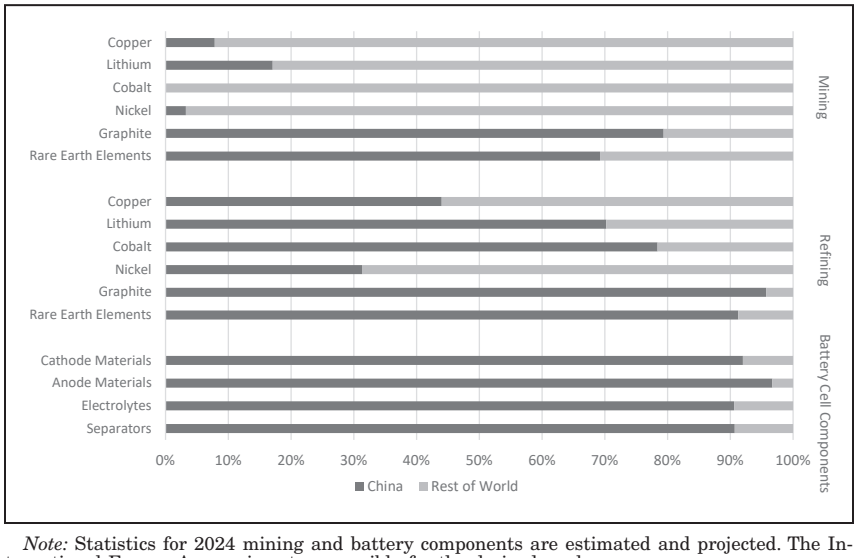
†Ironically, Pakistan's unreliable and expensive grid challenges originated in part from Chinese infrastructure investments, prompting it to increase its demand for Chinese solar panels. Humza Jilani, "Chinese Solar Panel Boom Threatens Pakistan's Debt-Ridden Grid," *Financial*

pears to be using legacy infrastructure ties to deepen energy dependence—positioning itself as both the partial cause of past bottlenecks and the provider of future fixes.

China Controls Critical Minerals—Key Inputs in New Energy Sectors

Not only does China dominate the manufacturing of new energy products as final outputs, it also controls critical minerals as key inputs that power these sectors. China is the leading refiner of 19 out of 20 energy-related critical minerals such as lithium, cobalt, graphite, and rare earth elements (REEs) (see Figure 6).[117] In 2024, China maintained near monopolistic control over both the global mined production and processing of graphite—used in core energy transition products such as lithium-ion batteries and solar panels (see Figure 6).[118] Chinese firms also own large shares of mines for energy-related critical minerals with proven reserves found mostly or entirely outside of China, such as lithium and cobalt, respectively.[119] Control over extraction supports Chinese firms' dominance in processing.[120]

Figure 6: China's Share of Output Across the Global EV and Lithium-Ion Battery Supply Chains, 2024



Note: Statistics for 2024 mining and battery components are estimated and projected. The International Energy Agency is not responsible for the derived work.
Source: U.S. Geological Survey, International Energy Agency, and Yano Research Institute.[121]

China's global monopolistic position is particularly pronounced in REEs, a subset of critical minerals that includes 17 elements with unique properties like strong magnetism. While REEs are abundant and dispersed globally, most major miners ship them to China for refinery due to financial and environmental costs. Chinese firms now account for 60 percent of extraction, 85 percent of processing, and

Times, September 17, 2024; Azeem Azhar and Nathan Warren, "Is Distributed Solar Energy a Game-Changer for Emerging Economies?" *World Economic Forum*, October 9, 2024.

over 90 percent of permanent magnet production.[122] As a result, the United States relies on China for 70 percent of its rare earth compounds and metals imports, increasing U.S. vulnerability to China's potential to weaponize this dominance in the supply chains during periods of geopolitical tension.[123] To maintain China's state control over REE supply chains, the State Council issued the Rare Earth Management Regulations in 2024 to guide further development and use of rare earth resources and create a new REE supply chain traceability system.[124] Since 2022, China has also poured more than 100 billion renminbi (RMB) ($13.8 billion) annually into geological exploration, including on REEs.[125]

For minerals not abundant at home, Chinese state-owned enterprises (SOEs) invest in mining and processing operations overseas. In Latin America, Chinese companies have invested in the "Lithium Triangle"—Argentina, Bolivia, and Chile—which together comprise nearly half of the world's lithium reserves.[126] China's Ganfeng Lithium acquired a majority stake in Argentina's Caucharí-Olaroz to operate the lithium brine mine, which produced 25,400 tons of lithium carbonate in 2024, exceeding initial production forecasts.[127] While such partnerships with Chinese lithium miners offer a pathway for Argentinean firms to benefit from Chinese expertise in mining, processing, and refining and to become more integrated in the global lithium market, they also risk giving China effective control over Argentina's mining infrastructure. Even when China does not own the mines, it can control offtake rights at some U.S.-owned mines.[128] For example, the Minerals Security Partnership, a U.S.-led initiative, supported Brazil's Serra Verde rare earth mine that is currently contracted to ship rare earths to China for processing at least until 2027.[129] (For more on U.S. dependency on China's critical minerals, see Chapter 9, "Chained to China: Beijing's Weaponization of Supply Chains.")

China Expands Overseas Greenfield Investments in New Energy Product Manufacturing

China's growing investment in overseas manufacturing of new energy products also positions it to control an ever-larger share of these new energy sectors globally. Chinese firms are expanding their production of new energy products overseas by ramping up greenfield foreign direct investment (FDI) in developing countries.* According to Climate Energy Finance, China's announced and confirmed greenfield FDI in new energy factories was estimated to reach $33.8 billion in 2024, a 42 percent increase from 2023.[130] These greenfield investments are focused on constructing wind, solar, batteries, and new energy vehicles, with more than half going to battery plant construction.[131] Chinese investments in new energy product manu-

*There are existing challenges in collecting FDI in an accurate and timely manner, in part because announced transactions may take several years to materialize or not at all. For example, BYD announced an EV factory greenfield investment in Mexico in 2023 but later cancelled its plans amid uncertainties stemming from the Chinese government's tech transfer concerns and Mexico's tariff talks with the United States. Tomohiro Ichihara and Shizuka Tanabe, "Mexico Blocks BYD EV Factory, Putting US Tariff Talks First," *Nikkei Asia,* July 4, 2025; "China Is Withholding Approval for BYD's Mexico Plant Due to Tech Concerns," *Mexico Daily,* March 19, 2025; Leonard Lara, "BYD Shelves Plans to Build Major Mexico Car Plant Over Trump's Trade War," *Bloomberg*, July 2, 2025.

facturing are spread across emerging economies such as in Eastern Europe, Southeast Asia, and the Middle East.[132]

To circumvent U.S. trade barriers on Chinese solar panels in the early 2010s, Chinese solar firms shifted their manufacturing to Malaysia, Vietnam, Thailand, and Cambodia, and in August 2023, the U.S. Department of Commerce imposed AD/CVD orders on certain solar cells and modules from those four countries for circumventing orders on China.[133] In June 2025, the Department of Commerce issued additional CVD orders on solar products from those countries after finding solar manufacturers imported subsidized components and received subsidized BRI loans from China.[134] For EVs, Chinese firms turn to key countries to enter and dominate the automotive markets in each region. In Thailand alone, several Chinese automakers such as BYD, SAIC, and Great Wall Motors announced 13.9 billion RMB ($1.94 billion) in greenfield FDI, turning the country into a regional EV manufacturing hub.[135] Chinese battery giant CATL announced a 7.34 billion euro ($8.2 billion) battery plant in Hungary in 2022, set to begin production this year, calling it a major step in its global expansion in Europe.[136]

Chinese firms have been ramping up their investments in new energy manufacturing overseas, in part due to emerging economies' pushback against China's global overcapacity dumping and desire for Chinese new energy knowhow. After Chinese automakers accounted for 85 percent of Brazil's EV market in 2024, the Brazilian government reintroduced a 10 percent tariff on EV imports and filed an antidumping case against BYD and Great Wall Motors.[137] At the same time, Brazil has encouraged more Chinese investments, with Great Wall Motors announcing a 10 billion Brazilian real ($1.83 billion) investment over the next decade.[138] Turkey also threatened to impose a 40 percent tariff on China's EVs in June 2024 and forced importing EV companies to invest in the country as BYD was considering a $1 billion FDI for EV production.[139]

While developing countries hope for technology transfer, capacity building, and more local employment from Chinese FDI, they do not always receive these benefits. China's Ministry of Commerce has begun instructing Chinese automakers to protect their EV knowhow when localizing their manufacturing abroad.[140] Additionally, Chinese firms sometimes rely on imported Chinese labor. For example, a BYD contractor reportedly brought Chinese workers to Brazil to work as cheap labor, often through arrangements that disrupted the local labor economy and violated labor laws.[141]

China Continues BRI Investments in Overseas Energy Generation Infrastructure

China's BRI continues to support energy generation infrastructure worldwide, distinct from its investments in manufacturing facilities (discussed above) or its growing ownership of host-country grid infrastructure (discussed below). First, BRI lenders have shifted from policy banks to commercial state-owned banks since 2021, in part due to China's domestic fiscal pressure and political backlash against Beijing's lending habits.[142] Between 2013 and 2020, China's policy banks lent an average of $14.8 billion in energy-related projects annually.[143] For example, Chinese firms own and have

been operating the Las Bambas copper mine in Peru since a $6.96 billion acquisition financed by Chinese policy banks in 2014.[144] In 2018, China Development Bank and South Africa's state-owned energy utility company signed a $2.5 billion loan contract to build the 4,800 megawatt Kusile coal-fired power plant.[145]

However, China's policy banks' lending activity in the energy sector slowed dramatically between 2021 and 2024, financing only a small fraction compared to the amount of loans during the 2013–2020 period.[146] On the other hand, China's state-owned commercial banks—such as Bank of China and Industrial and Commercial Bank of China—have overtaken its policy banks as lenders for energy projects since 2018.[147] Energy-related construction and investment deals reached $123.3 billion in the first half of 2025, twice the value of the first six months of the previous record in 2024.[148]

Second, China is working to promote BRI lending in "greener" energy sectors, but progress is slow as investments in carbon-intensive energy generation infrastructure continue to soar. In 2021, Xi Jinping delivered a speech at the UN General Assembly, promising that "China will step up support for other developing countries in developing green and low-carbon energy, and will not build new coal-fired power projects abroad."[149] Deals in low-carbon energy sectors such as solar, wind, and waste-to-energy were at their highest in 2024, accounting for 30 percent of China's total BRI lending.[150] For example, China engaged closely with Uzbekistan in low-carbon energy sectors, having built multiple solar and wind energy plants.[151] To improve Uzbekistan's energy security, for instance, the Uzbek Ministry of Energy entered a contract with CEEC Energy China, Huaneng Renewables Corporation, and Poly Technologies in 2023 to build $4 billion worth of solar photovoltaic power plants.[152] However, in the first half of 2025, BRI lending in oil and gas accounted for nearly 70 percent of BRI lending in energy-related projects.[153] One of the largest construction deals was Nigeria's $20 billion Ogidigben Gas Revolution Industrial Park, aimed at becoming Africa's largest gas processer.[154] China has also continued constructing coal-fired power plants abroad "in direct violation of the 2021 pledge."[155]

China's Growing Role in Global Energy Systems Creates Supply Chain and Cybersecurity Risks

There are several risks to the United States from China's growing role in global energy markets and systems (see Table 3 for a summary of this section's analysis). First, China's dominant position in certain sectors and components of electricity generation and transmission technologies, including critical minerals, means the United States may have growing dependence on China for these products, especially as artificial intelligence data center investments stimulate increased demand for electricity. Second, Chinese ownership and operation of energy infrastructure abroad enhances China's ability to put at risk critical energy infrastructure in other countries. Finally, both of these phenomena exacerbate China's capacity for cyber-enabled surveillance and sabotage of critical infrastructure. Together, these dependencies increase the risk that Beijing could coerce, disrupt, or destabilize U.S. and allied energy systems during a future crisis.

Table 3: Risks from China's Growing Role in Global Energy Systems

Risk	Level of Risk	Level of Existing Information on the Extent of the Risk	Risk to United States or Other Countries?
Dependence on Chinese Exports	High (over 50 percent dependent): Batteries and Low-Voltage Transformers Medium (over 20 percent dependent): Inverters and Rectifiers Unknown (imported via third countries): Solar Panels and Wind Turbines	High*	Both
Dependence on Chinese Critical Minerals	High	High	Both
Chinese Ownership and Operation of Energy Infrastructure	Medium	Low	Primarily to Other Countries
Cyber-Enabled Surveillance and Sabotage	High	Medium	Both

Note: Customs data can provide useful information on dependence on Chinese finished exports and some components, but such data may obscure where components in finished goods imports are sourced from.

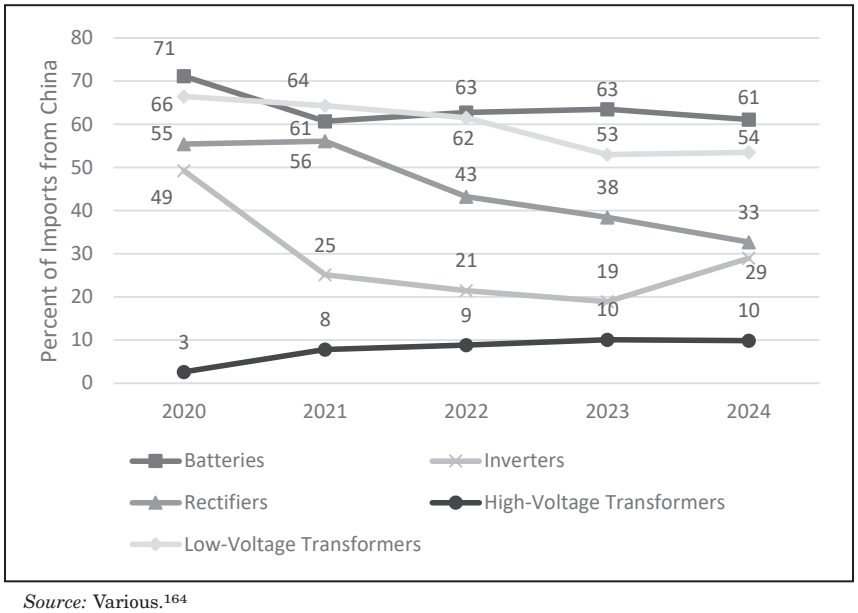
Dependence on Chinese Energy Exports Gives China Leverage

U.S. reliance on Chinese imports for many products and components used to generate, transmit, and distribute electricity could be used as geopolitical leverage by Chinese policymakers. As shown above in Table 2, "Chinese Overcapacity and Dumping in Global Energy Markets," China dominates global solar power manufacturing with over 80 percent of global market share across the supply chain. Raw import data disguise U.S. reliance on China for solar panel imports. Due to various trade remedy duties—as well as forced labor bans—imposed on Chinese solar imports, Chinese-made solar equipment is generally not imported into the United States from China, Hong Kong, or Macau but rather transshipped through third countries.[156] Chinese solar firms ship parts and components from their operations in China to third countries, where they assemble their solar panels and then export them to the United States.[157] Additionally, since Chinese manufacturers dominate numerous elements of the solar energy supply chain, even non-Chinese suppliers not focused on tariff evasion likely rely on Chinese components. According to the International Energy Agency, 50 percent of silicon wafers and 71 percent of solar cells used for solar panels in Europe come from China.[158]

The United States is especially reliant on China for power transmission and distribution equipment, including battery energy storage systems (BESS) (see Figure 7). BESS are technologies used both to store electricity for later use and to smooth out grid operations during peak load times. Sixty-one percent of imported non-EV lithium-ion batteries came from China in 2024.[159] When narrowed down to BESS and their components, S&P Global found that approximately half of the United States' imports since 2021 have come from China.[160]

The United States also depends on China for transformers, inverters, and rectifiers—products that convert electric currents for various purposes, including to transmit electricity over long distances and convert electricity distributed by substations into electricity usable by electronic devices. Fifty-four percent of imported low-voltage transformers were sourced from China in 2024, and while high-voltage transformer imports are low, they increased from 3 percent in 2020 to 10 percent in 2024.[161] The United States depends on China for 29 percent of inverters and 33 percent of rectifiers.[162] Energy management systems, smart meters, and advanced metering infrastructure used for smart grid management are also increasingly being sourced from Chinese vendors.[163]

Figure 7: U.S. Dependencies on Chinese Power Transmission Equipment, 2020–2024



Source: Various.[164]

U.S. and third-country electricity generation, transmission, and distribution equipment manufacturers also source critical components from China, although these indirect dependencies are more difficult to track. One example is nacelle modules, the main power-generating component and essentially the engine room of wind turbines.[165] While only 8 percent of wind turbine components im-

ported directly to the United States come from China, the use of Chinese components in imported finished wind turbines hides the true level of U.S. dependence on China.[166] The three largest installers of wind turbines outside of China—Vestas, Siemens Gamesa, and General Electric—have increasingly sourced nacelles from their factories in China, in some cases making China the primary source.[167] Siemens Gamesa, the second-largest installer of wind turbines outside of China, now relies almost exclusively on China for permanent magnets and related REE inputs.[168]

Power grids also rely on industrial control systems with Chinese components to synchronize, monitor, and control the flow of electricity through thousands of substations across the country.[169] These control systems rely on power electronics, chips, programmable logic controllers, and other digital technology.[170] Over 90 percent of all power electronics, battery technology, control components, and electronic sensors contain at least one critical component sourced from China, and at least 70 percent are fully made in China.*[171]

These various dependencies could be used by China as leverage against the United States. China has a history of economic coercion, including restricting the export of minerals like graphite and REEs to Europe, Japan, and the United States during political disputes.[172] China has already begun to use its exports as a tool of geopolitical leverage. In October 2024, China used its export control regime to cut off U.S. drone firm Skydio's access to batteries produced by the China-based subsidiary of a Japanese company because Skydio sells drones to Taiwan's fire agency.[173] Skydio responded by rationing batteries, sending one per drone instead of three as it searched for new suppliers.[174] U.S. imports of Chinese transformers are especially concerning because there is a global transformer shortage, with lead times for delivery of the largest transformers up to three to five years.[175] This shortage is already delaying U.S. power grid recoveries from natural disasters and slowing attempts to build data center infrastructure to support artificial intelligence development. Shortages could grow worse if China weaponized U.S. reliance on those imports.[176] A disruption to BESS or transformer imports during a crisis could severely impair grid recovery, delay emergency response, and increase the risk of prolonged blackouts.[177]

China Controls Key Components of Nuclear Fusion Supply Chains

China is investing in nuclear fusion as part of its long-term energy security and self-sufficiency strategy, explicitly prioritizing it in the 14th Five-Year Plan.[178] Unlike nuclear fission, which produces energy by splitting uranium and plutonium atoms, nuclear fusion produces energy by combining hydrogen atoms—offering the potential for cleaner, safer, and more abundant energy.[179] Fusion has the potential to generate four times more energy per kilogram of fuel than fission while producing minimal long-lived, low-level radioactive waste and no high-level radioactive waste.[180]

*Power electronics are devices that control and convert electric power. They include inverters—devices that convert DC power to AC power (e.g., electricity generated by solar panels to electricity used in power grids)—and rectifiers—devices that convert AC power to DC power (e.g., electricity used in power grids to electricity used in electronic devices).

China Controls Key Components of Nuclear Fusion Supply Chains—*Continued*

Nuclear fusion is still in an experimental stage, so it is unclear what technological approaches will work.[181] The United States and China are each responsible for key innovations in different approaches to achieving fusion.[182] In inertial confinement fusion, which uses lasers, as of April 2025 the U.S. Lawrence Livermore National Laboratory has achieved fusion ignition—producing more energy from the fusion reaction than was delivered by the lasers—eight times since 2022.*[183] In magnetic confinement fusion, which uses magnets, China set world records for the longest stable fusion reactions in 2023 and 2025, although those records were surpassed in February 2025 by a French reactor.[184]

A pressing challenge for fusion companies is that continued funding is needed to develop new fusion supply chain inputs like heat- and radiation-resistant materials, fusion fuel production methods, and powerful lasers.[185] When government and private funding are combined, the United States reportedly spends over twice as much as China on nuclear fusion projects, and U.S. firms have attracted over $7.5 billion of the almost $14 billion in equity investments made in fusion companies globally since 2010.[186] However, according to the Special Competitive Studies Project, the Chinese government has spent at least $5 billion (and likely well over $10 billion) on fusion since 2023, more than twice the $2.3 billion appropriated to the U.S. Department of Energy's (DOE) Fusion Energy Sciences program from fiscal year 2023 to 2025.†[187] U.S. private funding for fusion has fluctuated significantly, and China's government-led funding lends itself to patient, long-term capital, leading analysts to conclude that the steady pace of Chinese spending could surpass more variable U.S. spending in the long run, allowing China to invest more in critical parts and components.[188]

China already controls key inputs into fusion supply chains. In July 2025, China formally launched its first national fusion SOE—China Fusion Energy.[189] Previously, China had brought together upstream and downstream research facilities, mining and metals companies, and power utilities to invest in developing new components and materials needed for fusion, including a multi-company innovation consortium and at least one industrial park hosting fusion-related industries.[190] China leads in the

*The April 2025 experiment produced over four times the energy delivered by the lasers. However, the energy consumed by the laboratory's laser facility is roughly 100 times larger than the amount delivered by the lasers, meaning less than 5 percent of the total energy consumed was released by the fusion reaction, so these experiments "[do] not imply net energy gain from a practical fusion energy perspective." Lawrence Livermore National Laboratory, *Achieving Fusion Ignition*, accessed July 16, 2025; Charlie Osolin, "LLNL's Breakthrough Ignition Experiment Highlighted in Physical Review Letters," *Lawrence Livermore National Laboratory*, February 6, 2024.

†DOE's Fusion Energy Sciences program is the only DOE program dedicated to fusion energy commercialization. For other fusion-related programs, from fiscal year 2023 to 2025 Congress appropriated $2 billion for the National Nuclear Security Administration's Inertial Confinement Fusion program, which primarily conducts non-commercial fusion experiments, and from fiscal year 2020 to 2023 DOE's Advanced Research Projects Agency-Energy obligated $75 million to commercial fusion development. "FY2026 National Nuclear Security Administration," *American Institute of Physics*, September 4, 2025; U.S. Government Accountability Office, *Fusion Energy: Additional Planning Would Strengthen DOE's Efforts to Facilitate Commercialization*, January 2025, 4, 12.

China Controls Key Components of Nuclear Fusion Supply Chains—*Continued*

production of certain components essential for tokamaks—the reactor used for magnetic confinement fusion and the one China has publicly prioritized—including REE magnets, capacitors, and pulsed-power components.[191] China is building a range of fusion reactor designs alongside tokamaks and is investing in foundational supply chains to obtain a "first-mover advantage" in whichever design proves successful.[192] Supply of fusion components is already tight, and U.S. companies often source specialty components from China.[193] Some manufacturing of these components could be reshored; it took one U.S. fusion firm three years to import the capacitors it needed to build its prototype, and that firm is now investing in U.S.-based capacitor manufacturing for future reactors.[194]

China's Dominance in Energy-Related Critical Mineral Refining Creates Supply Chain Vulnerabilities*

As discussed above, China is the leading refiner for 19 of 20 critical minerals necessary in the energy sector, and it is weaponizing that dominance in critical mineral refining supply chains (i.e., using its control of those supply chains for "coercive political purposes") by both restricting access to minerals through export controls and flooding global mineral markets to put competitors out of business.[195] China has weaponized its control of energy-related critical minerals in the past, both for political purposes and to protect its supply chain dominance. At various times since 2010, China has flooded the global market with REEs, putting the United States' only REE mine and refinery out of business; blocked exports of REEs to Japan, the United States, and Europe during political disputes; and blocked graphite exports to Sweden to prevent the expansion of Swedish battery maker Northvolt.† [196] Since July 2023, China has subjected certain energy-related minerals technologies to formal export licensing regimes in retaliation against the United States' semiconductor export controls and tariffs.[197]

In April 2025, China subjected seven REEs and related materials to export controls.[198] This differed from earlier controls because it covered a large group of minerals with many different applications, almost none of which are processed outside of China.[199] The ensuing bureaucratic backlog, paired with hesitancy on the part of China's

*For a more extensive discussion of China's dominance in the critical minerals sector and its expanding export control regime to use the sector as leverage, see Chapter 9, "Chained to China: Beijing's Weaponization of Supply Chains." This subsection focuses on critical minerals necessary for the energy sector.

†After suspending operations in 2015, the U.S. REE mine—the Mountain Pass mine—reopened in 2018. In 2024, it resumed processing most of the material it produces. In 2025, the U.S. Department of Defense announced it would take a 15 percent stake in the company that operates the mine—MP Materials—and commit to a price floor for purchasing the mine's output. As a result, MP Materials plans to expand its processing capacity and build an REE magnet manufacturing facility. Jon Emont, "Pentagon to Take Stake in Rare-Earth Company, Challenging China's Control," *Wall Street Journal*, July 10, 2025; "MP Materials Announces Transformational Public-Private Partnership with the Department of Defense to Accelerate U.S. Rare Earth Magnet Independence," *MP Materials*, July 10, 2025; Keith Bradsher, "China Walks a Line in U.S. Trade Talks, Trying Not to Overplay Its Hand," *New York Times*, June 11, 2025.

customs and national security bureaus to license any materials that could arguably be subject to export controls, led factories in the United States, Europe, and Japan to stop or delay production of products with REE inputs, like automobiles and defense equipment.*[200]

In June 2025, after reaffirming an agreement reached between the United States and China in May 2025, China announced it would green-light shipments of REEs to commercial end users in the United States, but even as China's global REE exports returned to pre-control levels in July 2025, importers continued to report delays due in part to arbitrarily imposed chemical testing and analysis requirements and license approval processes that penalize businesses for not turning over IP and confidential business information.[201] These controls also affected other countries, in part because the United States largely imports critical minerals after they have been incorporated into manufactured components and finished products and also because China reportedly threatened to sanction companies in South Korea for re-exporting REE products from China.[202] In October 2025, Beijing expanded its export controls to include five additional REEs as well as REE processing equipment.[203] It also introduced extraterritorial provisions requiring companies in other countries to obtain a license from Chinese authorities to export products with more than 0.1 percent of their value derived from Chinese-sourced REEs and using REE processing technology.[204] These moves marked a significant escalation in China's willingness to project its dominance beyond its own borders and assert control over international downstream supply chains. (For more on China's use of export controls, see Chapter 9, "Chained to China: Beijing's Weaponization of Supply Chains.")

China's mineral export controls affect both new and traditional energy technology inputs. Affected minerals are crucial for new energy generation: REEs and molybdenum are used for wind turbines, antimony and gallium are used to manufacture solar panels, and graphite is needed for EV batteries.[205] However, these same minerals are also used in traditional energy technologies. Molybdenum is used in both coal and nuclear power plants, antimony is used to harden internal combustion engine vehicle chassis, REEs are used in a variety of other car parts from brakes to steering systems, and gallium and germanium are used to fabricate semiconductors critical to a wide variety of energy generation and transmission technologies.[206]

China's use of export controls and Chinese firms' use of their dominant global positions to flood mineral markets create risks of short-term and long-term scarcity. In the near term, export restrictions may make it difficult or impossible for U.S. companies in the energy sector to source both Chinese-refined critical minerals and components made from them (e.g., Japanese and Korean semiconductors, REE magnets, and batteries).[207] Shortages while China was ratch-

*Defense applications of REEs and other mineral exports controlled by China include energy generation and storage as well as radar, infrared lenses, armor-piercing munitions, and other crucial technologies. China's export controls do not allow these minerals to be sent to U.S. military end users. As a result, procurement costs for these minerals have increased more quickly than for other parts procured by the U.S. Department of Defense, and a drone parts manufacturer delayed orders as it searched for alternative sources of REEs. Jon Emont, Heather Somerville, and Alistair MacDonald, "China Is Choking Supply of Critical Minerals to Western Defense Companies," *Wall Street Journal*, August 3, 2025; "From Rock to Rocket: Critical Minerals and the Trade War for National Security," *Govini*, April 2025, 1, 6.

eting up enforcement before agreeing to relax restrictions led to U.S. factory closures and caused global prices to soar.[208]

Despite years of China making clear its intent to leverage its control of energy-related critical mineral refining, the United States has taken few actual steps to address this glaring point of Chinese leverage, and those that have been taken have been halting and inconsistent and involved small amounts of resources relative to the size of the threat. In the energy sector, the 2021 Infrastructure Investment and Jobs Act and 2022 Inflation Reduction Act included tax credits and funding for critical mineral projects as well as incentives for companies to incorporate non-Chinese minerals into advanced batteries and EVs.[209] The United States has also invested in multiple critical mineral firms that focus on minerals for global energy transition, including investments in TechMet through the International Development Finance Corporation in 2018 and Mountain Pass (MP) Materials through the Department of Defense in 2025.*[210]

As witnesses testified before the Commission, insufficient domestic demand, high production costs, and long development times continue to pose challenges to U.S. efforts to diversify away from China. U.S. efforts have struggled to create significant domestic production because U.S. domestic demand for minerals is not sufficient to support large-scale mining and refining.[211] Moreover, domestic producers' exports would not be able to compete with Chinese producers' lower costs and overcapacity, decreasing private investors' willingness to finance U.S. projects.[212] For now, the United States and many other countries remain heavily reliant on China for energy-related critical minerals and related components. (For more on U.S. efforts to reduce dependency on China for critical minerals and persistent challenges, see Chapter 9, "Chained to China: Beijing's Weaponization of Supply Chains.")

China Controls and Operates Energy Infrastructure around the World

Although not a significant threat in the United States, many countries have opened themselves up to risks from direct control over critical energy infrastructure by Chinese entities, often SOEs. Countries have ceded ownership of their critical electric infrastructure due to Chinese firms' advanced energy storage and transmission technology, stronger finances (often fueled by Chinese government support), and greater experience building and operating power grids.[213] Chinese firms have significant stakes in both developed and developing countries' grids (see Table 4 and Figure 8).†[214] Most recently, Chinese SOE State Grid expanded its transmission line

*The investment in MP Materials builds on earlier grants awarded to MP Materials and other rare earth and magnet firms to establish a mine, oxide production facilities, and magnet manufacturing facilities. C. Todd Lopez, "DOD Looks to Establish 'Mine-to-Magnet' Supply Chain for Rare Earth Materials," *Department of Defense Manufacturing Technology Program*, March 11, 2024.

†These investments may be motivated in part by State Grid's vision for a "Global Energy Interconnection" (GEI)—a network of ultra-high-voltage transmission lines and smart grids that would connect low-carbon electricity generators with electricity consumers across the globe. The GEI was endorsed by Xi Jinping at the UN in 2015, but since Xi has not mentioned it since 2017 and various private-sector and government actors frame it in different ways to promote their own interests, it is unclear to what extent the GEI continues to drive Chinese policy. "White Paper on Global Energy Interconnection: Development Strategy," *Global Energy Interconnection Development and Cooperation Organization*, accessed August 18, 2025, 2; Fiona Quimbre et al., "China's Global Energy Interconnection," *RAND Corporation*, December 5, 2023, 9, 14–15.

operations in Brazil, and in 2023, Italian firm Enel Perú sold its power distribution and supply businesses in Chile to Chinese SOE China Southern Power Grid.[215]

These Chinese investments in a country's critical energy infrastructure result in significant risks to the host country—including the potential for unauthorized Chinese access to industrial control systems, data transfer, surveillance of critical infrastructure, and even the threat of sabotage.[216] Such espionage can give insight into power flows, load patterns, and interconnection status, revealing information about commercial and military activities.[217] Access to industrial control systems can also be used to interfere with grid operations, leading to sabotage risks like power outages and fires.[218] (For more on risks from surveillance and sabotage, see "Embedded Chinese Components Exacerbate Risk of Cyber-Enabled Espionage and Sabotage" later in this chapter.) Aware of these concerns, some jurisdictions have begun to take measures to reduce their grids' exposure to China. Belgium, Germany, and the UK have blocked Chinese investment deals, and Czechia, Lithuania, and Romania have passed laws to block Chinese access to critical energy infrastructure.[219]

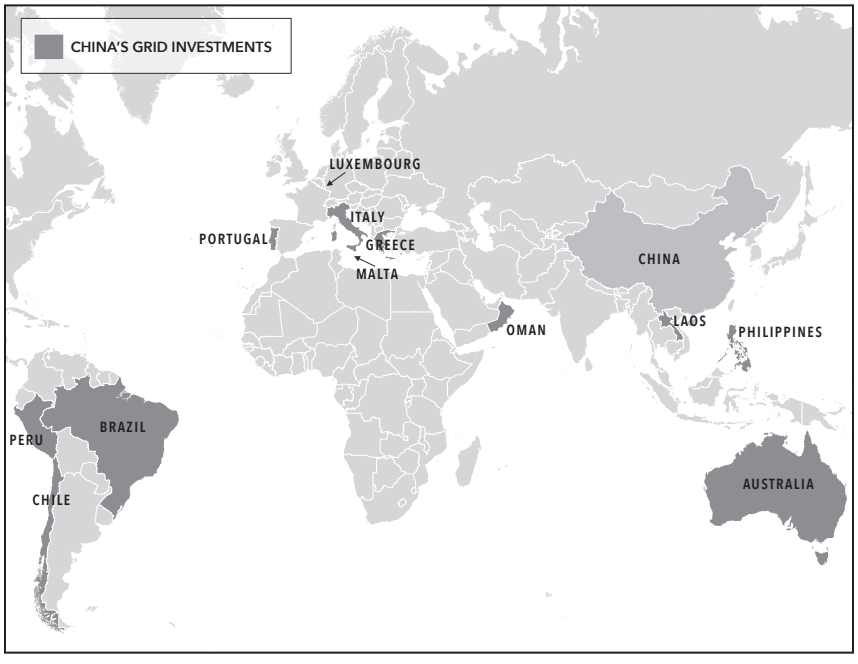
Table 4: Notable Chinese Investments in Power Transmission Grids

Country	Company with Chinese Investment	Percentage Owned by Chinese Firms
Australia	AusNet Services (Victoria), CitiPower Electricity Distribution Network Victoria (Victoria), ElectraNet Pty Ltd. (South Australia), Powercor Electricity Distribution Network Victoria (Victoria), SA Power Networks Electricity Distribution (South Australia), and SGSP (Australia) Assets Pty Ltd./Jemena (Australian Capital Territory, Victoria)	19.9 percent, 51 percent, 46.56 percent, 51 percent, 51 percent, and 60 percent
Brazil	CPFL Energia and State Grid Brazil Holding S.A.	83.71 percent and 100 percent (roughly 12 percent of national grid)
Chile	Compañía General de Electricidad S.A., Chilquinta Energía S.A., and Transelec S.A.	96.04 percent, 100 percent, and 27.79 percent (roughly 57 percent of national grid)
Greece	Independent Power Transmission Operator S.A./ADMIE	24 percent
Italy	CDP Reti SpA and Terna S.p.A.	35 percent and 29.85 percent (roughly 10–13 percent of national grid)
Laos	Électricité du Laos Transmission Company Ltd. (high-voltage transmission operator)	90 percent
Luxembourg	Encevo S.A.	24.92 percent
Malta	Enemalta	33 percent
Oman	Oman Electricity Transmission Company	49 percent

Table 4: Notable Chinese Investments in Power Transmission Grids—*Continued*

Country	Company with Chinese Investment	Percentage Owned by Chinese Firms
Peru	Luz del Sur and Pluz Energía	100 percent in more than half the country, including the capital
Philippines	National Grid Corporation of the Philippines	40 percent
Portugal	Redes Energéticas Nacionais, SGPS, S.A. and Energias de Portugal, S.A.	25 percent and 21.35 percent

Figure 8: Map of Notable Chinese Investments in Power Transmission Grids



Note: This is not an exhaustive list, and it may not reflect the full extent of Chinese investments.
Source: Various.[220]

While these risks are primarily experienced by the host country, they can affect U.S. national security interests to the extent that operation of infrastructure necessary for U.S. overseas presence and activities is subject to Chinese control. A notable case of these risks exists in U.S. treaty ally the Philippines. Chinese SOE State Grid has a 40 percent ownership stake in the National Grid Corporation of the Philippines, and State Grid's general manager is the chairman of the National Grid Corporation.[221] While most of the employees who operate the grid are Filipinos, in 2019 the president of the Philippine National Transmission Corporation, which oversees

the Philippine grid, indicated it would be possible for China to shut down the grid, and the overseer's limited access to the grid would prevent it from manually taking over until 24 to 48 hours after a shutdown.[222] A disruption during an invasion or other conflict could delay Philippine and U.S. civil defense and military responses.[223] The Philippine government acquired a 20 percent stake in the National Grid Corporation in 2025, giving it two board seats and the ability to monitor security threats, although State Grid maintains its 40 percent share, leaving uncertainty as to what could happen in a crisis.[224] The Commission heard conflicting information about continuing operational threats to the Philippine grid during its trip to Manila in 2025. (For more on risks posed by Chinese investment in Southeast Asia's critical infrastructure, see Chapter 4, "Crossroads of Competition: China and Southeast Asia.")

Embedded Chinese Components Exacerbate Risk of Cyber-Enabled Espionage and Sabotage

Chinese components, particularly internet-connected devices, create vulnerabilities for the U.S. power grid. Grid distribution systems increasingly use operational technology and industrial control systems that allow remote access for easier maintenance and more detailed data collection.[225] Every embedded internet-connected technology is a potential cybersecurity vulnerability, particularly if it cannot be self-contained or "air-gapped."[226] Unless mitigated by end users, Chinese-manufactured components with remote access capabilities could be modified or accessed by the manufacturer, creating additional vectors for Chinese surveillance and sabotage.[227] This risk is compounded by the United States' heavy reliance on China for key grid components, as discussed above.

Chinese Components May Enable Cyber Espionage

Cyber espionage uses digital systems to obtain confidential information.[228] Chinese-manufactured components can enable direct access to other parts of the grid or provide data that can be leveraged for deeper access, for example insights into grid configurations, load characteristics, and asset health that help identify targets to disrupt.[229] Successful intrusions often enable attackers to move through connected industrial control systems, gaining direct access to those systems.[230] This is how Russia compromised U.S. electric utilities from 2016 to 2018 by moving laterally via connected contractor and subcontractor systems.[231] Data collected in these attacks, such as personnel credentials, can be used to gain access to otherwise disconnected systems—for instance, through socially engineered spear phishing campaigns.[232]

This risk is not theoretical. Espionage and grid mapping were the primary functions of a Chinese intrusion into the U.S. power grid and other critical infrastructure. Since at least 2021, the Chinese state-backed cyber actor Volt Typhoon has infiltrated the U.S. power system to collect operational insights into the grid, identify chokepoints with outsized control over grid operations, and pre-position cyber assets for operational disruptions.*[233] According to reporting

*People's Liberation Army (PLA) strategists consider energy infrastructure information systems part of the "cyber electromagnetic" domain and consider one of the first requirements for

from the *Wall Street Journal*, Chinese officials tacitly acknowledged that Beijing was behind the Volt Typhoon hacks in a secret December 2024 meeting with U.S. counterparts—a rare admission of state support for cyberattacks that China's government routinely denies.[234] U.S. representatives at the meeting interpreted remarks from Ministry of Foreign Affairs cyber official Wang Lei as intending to deter U.S. involvement in a Taiwan conflict.[235] China has also compromised the energy infrastructure of other countries, most notably India. In April 2022, a cyber actor backed by China intruded into the networks of several organizations responsible for overseeing India's grid control and electricity dispatch but reportedly did not cause any damage.[236] As the cyber intrusions were concentrated in North India, analysts believe this activity may be related to China-India border disputes.[237]

Chinese Components Enable Cyber Sabotage

As demonstrated by Volt Typhoon pre-positioning for operational disruptions, China could remotely access electric grid components to sabotage the U.S. power grid. China has already used its offensive cyber capabilities to sabotage other countries' power grids. For example, in February 2021, Chinese state-backed cyber actor Red Echo infected India's power grid control systems with malware, causing a power outage in Mumbai that shut down trains and financial markets and forced hospitals, already in the midst of a COVID-19 outbreak, to turn on emergency power generators.[238]

Sabotage that brought down the grid or large parts of it could have a devastating and destabilizing impact. Although not caused by a cyberattack, the experience of Spain and Portugal in April 2025 demonstrates the havoc possible by a single substation outage that plays a vital role in the grid. Spain and Portugal's transportation, communication, payment, water, grocery, and financial systems all ground to a halt for 18 hours.[239] Unlike Spain and Portugal's more integrated grid, the U.S. grid is separated into three physical interconnections that share limited electricity, so there is not one single point of failure that could cause a nationwide outage. If one of these interconnections were to become disabled, however, it would have massive impacts on the United States.[240] More than 50 million people in the United States and Canada lost electricity in 2003 during North America's largest blackout when part of the Eastern Interconnection lost power. It is worth noting that energy management system servers and remote consoles were "key factor[s]" that made it more difficult for operators to monitor and control the power system.[241]

Even attacks targeting small portions of the grid that service military or other critical infrastructure could create disproportionate impacts on the U.S. economy or impede U.S. military responses.[242] For example, a ransomware attack on Colonial Pipeline's business systems in 2021 led them to disconnect operational systems for five

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cyber electromagnetic warfare to be "collecting wide-ranging intelligence on the enemy's network electromagnetic systems and information capabilities … especially its critical nodes and other key parts and easily exploitable weaknesses." The PLA has demonstrated its ability to act kinetically on such intelligence by simulating attacks on Taiwan's energy infrastructure. Enoch Wong, "PLA Takes Aim at Taiwan's Coastal Fuel Depot in Strait Thunder 2025A War Games," *South China Morning Post*, April 3, 2025; Xiao Tianliang, ed., 战略学 [Science of Military Strategy], (China's National Defense University Press, 2020), 235, 238–239.

days and caused gas stations to run out of fuel in 13 states and Washington, DC, demonstrating the outsized effect of an attack on one critical energy company.[243]

Inverters and battery energy storage systems are particularly vulnerable to cyberattacks. Undocumented communication devices that could bypass utility companies' firewalls have been found in some Chinese solar power inverters as well as some Chinese batteries.[244] Additionally, inverters are increasingly internet connected, providing users with real-time data collection and remote access.[245] In November 2024, a number of solar power inverters—devices that convert direct current from solar panels into electricity usable by households—installed at U.S. homes were disabled by the Chinese manufacturer, Ningbo Deye Technology.[246] The inverters in question were not authorized for sale in the United States and were either disabled remotely or shut down by an authorization verification mechanism installed on the inverters.[247] Although the incident was intended to enforce an exclusive commercial distribution agreement and not an act of sabotage, it nonetheless shows that Chinese-made internet components in the U.S. power system can be remotely manipulated by the manufacturer or come installed with internet-connected software that will disable them under certain conditions—a vulnerability with serious national security implications.[248] A cyberattack on solar inverters could direct them to either cut off solar power generation assets or add more power to the grid, leading to voltage and stability issues in the local distribution system, damaged and tripped equipment, and possibly a power outage.[249]

Battery energy storage systems pose a special risk to the U.S. electric grid because faulty batteries may cause not only outages but also fires near other grid infrastructure, with the potential for wide-ranging consequences.[250] In January 2025, one especially high-profile battery fire took place at a grid storage facility in Moss Landing, California—the second-largest grid-scale storage facility in the world.[251] A failure in one of the facility's fire suppression systems forced 1,700 people to evacuate, closed part of a highway, and may have caused damage to the environment and nearby residents' health.[252] Although that fire was not the result of a cyberattack, "thermal runaway events" in batteries can be caused by malicious firmware, making battery systems a potential vector for grid sabotage.[253]

U.S. Power Grid Regulatory Environment Poses Cybersecurity Challenges

The fragmented nature of regulatory authority over the U.S. power grid poses challenges to creating and implementing effective, uniform cybersecurity regulations. The interstate "bulk power system" is regulated by federal agencies, while local distribution and retail sale are regulated by state and local entities.*

*There are three primary types of distribution utilities: investor owned, publicly owned, and cooperatives. Investor-owned utilities are overseen by state public utility commissions; publicly owned utilities are overseen by local city councils or by elected or appointed boards; and cooperatives are private, member-owned utilities (often rural) that are overseen by their members. U.S. Government Accountability Office, *Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems*, March 2021, 6–7.

U.S. Power Grid Regulatory Environment Poses Cybersecurity Challenges—*Continued*

Some legislation and executive actions have sought to improve the reliability and cybersecurity of the power system, but Chinese components remain embedded in the U.S. power grid.

At the federal level, the main players in U.S. power grid regulation are the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC). The Federal Power Act gives FERC jurisdiction over interstate transmission and wholesale sales of energy (often called "the bulk power system").[254] FERC is responsible for grid reliability in the United States.[255] Since the U.S. bulk power system is connected to the grids in Canada and Baja California (Mexico), NERC—a North American-wide reliability organization—is needed to develop and enforce mandatory reliability standards in all three countries.[256] NERC is an industry-led organization that FERC has designated as the United States' Electric Reliability Organization.[257] Thus, FERC relies on NERC to issue reliability standards—including cybersecurity standards—although FERC can direct NERC to issue standards and revise its proposed standards.[258] NERC standards are not mandatory until approved by FERC.[259] The U.S. Department of Energy (DOE) also plays a role in the U.S. power grid through the bulk power transmission assets operated by its Power Marketing Administrations and by coordinating industry, state, and federal responses to cybersecurity incidents and providing technical assistance to the energy sector as the Sector-Specific Agency for critical energy infrastructure cybersecurity.[260]

FERC and NERC do not have jurisdiction over local distribution or retail sale, which is regulated by state and local entities (typically known as Public Utility Commissions, or PUCs).[261] Federal agencies cannot mandate compliance from PUC-regulated utilities—many of them privately owned—but they do work with other federal agencies to coordinate cybersecurity information-sharing efforts through the Electricity Information Sharing and Analysis Center (E-ISAC), issue cybersecurity standards and frameworks, and perform exercises and evaluations that utilities can use to assess their cybersecurity (such as the biennial GridEx exercise).[262]

The United States' two-tier, decentralized approach to grid regulation can limit the effectiveness of federal action and the deployment of cybersecurity best practices.[263] Federal action is limited to the bulk power system, leaving almost 3,000 distribution utilities outside federal jurisdiction.[264] Some local distribution systems regulated by PUCs are operated by small, independent utilities.[265] In testimony before the Commission, one witness noted that smaller utilities typically have lower funding and lower cyber defenses.[266] As other U.S. government reports have noted, small businesses in the energy sector with limited cybersecurity capabilities may be particularly vulnerable to the advanced persistent threat of state actors.[267] The Cyberspace Solarium Commission identified similar systemic risks in the water sector in

U.S. Power Grid Regulatory Environment Poses Cybersecurity Challenges—*Continued*

its 2020 report, recommending federal coordination, continuity of the economy planning, and secure infrastructure design to defend against foreign cyber intrusion and sabotage.[268] These recommendations remain highly relevant in the context of China's embedded footprint in U.S. and global energy systems.

Some legislation and executive actions have directed improvements to protect the U.S. power grid from risks posed by Chinese components and cyberattacks, but most have taken a broader approach to the security of critical infrastructure. Pursuant to a May 2020 Executive Order (EO), DOE issued a "Prohibition Order" preventing the sourcing of certain bulk power grid equipment from Chinese-influenced entities for specified infrastructure serving "critical defense facilities."[269] The same EO ordered an interagency examination of approaches to mitigate risk from existing bulk power equipment sourced from foreign adversaries but stopped short of directing actions such as replacing Chinese components.[270] In April 2021, DOE's Prohibition Order was revoked and DOE announced a "100-day plan" to enhance the cybersecurity of electric utilities and secure energy sector supply chains.[271] Subsequent EOs and National Security Memoranda encouraged the deployment of industrial control system cyber monitoring technologies and directed federal agencies to standardize cybersecurity incident response procedures, provide technical assistance, enhance information sharing, and deploy existing authorities to encourage private-sector compliance with security and resilience requirements for the critical infrastructure sectors under their purview.[272] The 2021 Infrastructure Investment and Jobs Act directed FERC to establish incentives to encourage investments in advanced cybersecurity technology and participation in cybersecurity threat information-sharing programs beyond what mandatory standards require, and the 2022 Cyber Incident Reporting for Critical Infrastructure Act mandated bulk power grid entities to report cybersecurity incidents and ransomware payments.[273]

The division of labor between federal, state and local, and private entities makes it difficult to address the risk posed by Chinese components already installed in the U.S. power grid. Given the scale of existing Chinese components in U.S. electricity infrastructure, rip-and-replace measures may be very expensive because utilities are entitled to recover a reasonable rate of return on investments in transmission and distribution systems, which can include regulatory costs incurred due to federal action, a cost that is then passed on to consumers.*[274] Rip-and-replace measures in the telecommunications sector have been impeded by lack of funding.[275] This suggests other mitigation efforts may be needed. Other solutions that have been suggested in lieu of broad rip-and-replace orders include targeted rip-and-replace measures for the most critical equipment and locations; hardware, firm-

*Federally regulated transmission utilities are allowed to recover "all prudently incurred costs necessary to comply with mandatory reliability standards" issued under Section 215 of the Federal Power Act. Energy Policy Act of 2005 § 1241, Pub. L. No. 109–58, codified at 16 U.S.C. § 824s.

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ware, and software replacement for existing equipment; isolating and monitoring vulnerable equipment to ensure it is not acting abnormally; and ensuring that future installations adhere to cyber-informed engineering principles that physically prevent cyberattacks from having system-wide effects.*[276]

Implications for the United States

China's electricity-centric energy strategy and its investments in new and emerging electricity generation and transmission technologies are shaping the global energy system. Chinese companies in the energy sector seek to maintain their competitive edge over U.S. companies through subsidized, aggressive pricing strategies and the Chinese government's formal and informal curbs on technology transfer.

China's focus on electrification may reduce its dependence on imported energy sources, particularly imported fossil fuels for transportation. The massive scale of low-carbon energy installations and widespread adoption of electric technologies in China may have begun chipping away at its oil consumption. In its *2024 Annual Report to Congress*, the Commission analyzed China's large stockpiling efforts around oil, indicating China feels a significant vulnerability around this dependency. **If China succeeds in reducing its reliance on imported oil and gas, it may affect the extent to which China views this vulnerability as a constraint on more disruptive activity.** (For more on China's efforts to stockpile energy resources and reduce its reliance on imported oil and gas, see U.S.-China Economic and Security Review Commission, Chapter 7, "China's New Measures for Control, Mobilization, and Resilience," in *2024 Annual Report to Congress*, November 2024, 458–539.)

The United States is exposed to leverage from China's dominant role in inputs to and components used in the energy sector. The United States has been targeted by China's export controls on critical minerals, many of which are vital to the energy sector. The United States also relies on China for key technologies and components in the energy sector. The United States currently lacks the capability to rapidly scale production of critical energy components such as transformers, inverters, and grid-scale batteries. **Absent a coherent surge strategy, any disruption to these supply chains could leave the U.S. grid dangerously exposed in a contingency.**

The United States has yet to adequately address risks inherent in allowing connected Chinese components into U.S.

*Cyber-informed engineering principles focus on designing power grids with manual overrides, isolated and segmented systems, and operational redundancies that limit the potential impact of cyberattacks. In testimony before the Commission, one witness described how cyber-informed engineering in the water sector could look like making the pipes that deliver chlorine to the water system so small that it would be physically impossible for a cyberattack to dump excess chlorine into U.S. drinking water. Patrick Miller, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Domestic Energy Challenges and Its Growing Influence over International Energy Markets*, April 24, 2025, 112, 173.

energy infrastructure. The United States is particularly at risk from its reliance on Chinese-manufactured battery energy storage systems, inverters, transformers, and other high-impact components with remote access capabilities. The Volt Typhoon attack demonstrates the possibility that connected Chinese components may provide vectors for China to sabotage key portions of the bulk power and distribution systems as a means of leverage or during a conflict. Federal authority to mandate mitigation measures is currently limited, and addressing this risk will require greater coordination between federal and state and local authorities.

Further exacerbating the cyber risks from Chinese-connected components in U.S. energy infrastructure, pre-positioning cyber campaigns like Volt Typhoon often evade detection for months or years. This visibility lag creates windows in which U.S. response options are constrained or delayed. **Unaddressed cyber vulnerabilities increase the risk that China could disable or disrupt portions of the power grid before U.S. operators even become aware of the threat—especially in the early stages of a contingency or crisis.**

The U.S. Armed Forces and other assets stationed overseas may rely on power grids that are controlled or influenced by Chinese entities, creating opportunities for Beijing to conduct surveillance or disable power to critical facilities during a crisis, conflict, or other contingency. Even temporary outages could degrade mission-essential functions—such as command and control, logistics coordination, and air defense—particularly in contested or austere environments. Many facilities supporting U.S. and allied operations depend on host-nation infrastructure with limited backup capacity, compounding operational vulnerabilities. These risks are especially acute in strategically important regions such as the Indo-Pacific, where Chinese firms maintain a significant footprint in grid operations and infrastructure development across multiple allied and partner nations.

China's leverage in international energy markets could also have implications for the United States. **A third country may be less willing to align with the United States when U.S.-China interests diverge if the country is concerned such action will expose it to threats of economic coercion from China—whether relating to access to critical minerals needed for manufacturing or Chinese operation of energy infrastructure.** China's significant capabilities in low-carbon energy also provide it an important tool for "green diplomacy" to the extent third countries continue to prioritize reducing carbon emissions and otherwise take actions to enhance resilience of their energy systems, reduce reliance on imported energy sources, and reduce risks from climate change.

China is also increasingly active in international standards-setting bodies for energy systems, and its dominance in certain market segments and overseas investments provide it de facto global influence over certain energy sector-related standards. **Given that standards in the energy sector may have implications for competitiveness, surveillance, and cybersecurity, the United States should ensure it remains an active participant in relevant international standards-setting efforts.**

Recommendations

The Commission recommends:

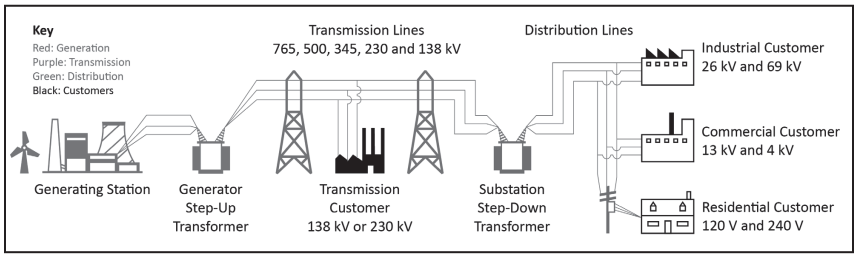
- To protect the U.S. power grid from the economic and cybersecurity threats posed by Chinese-made components, Congress should:
  - Prohibit the import of energy storage systems with remote monitoring capabilities that are manufactured by or made with technology licensed from Chinese entities.
  - Allocate additional funds to the U.S. Department of Energy for grid expansion, modernization, and cybersecurity grant and loan programs and prohibit the use of those grants and loans to purchase goods or services or license technology from entities that pose a cybersecurity risk to the U.S. power grid to be designated by the Secretary of Energy, in coordination with the Secretary of Defense, Secretary of Homeland Security, the Director of the National Security Agency, and the heads of other federal departments and agencies, as the Secretary determines appropriate.
  - Direct the Department of Energy and Federal Energy Regulatory Commission to strengthen supply chain risk management requirements for interstate electric transmission utilities by:
    - Requiring utilities to identify all Chinese-origin components within their high- and medium-impact bulk electric system and protected cyber assets;
    - Developing requirements to prohibit the installation of or mitigate the cybersecurity risk posed by those components;
    - Requiring that future procurement of such cyber assets come with full software, firmware, and hardware bills of materials;
    - Mandating that interstate transmission utilities report on their use of Chinese-origin components to their distribution utility customers; and
    - Coordinating with the U.S. Department of Homeland Security and other relevant agencies to provide technical assistance to implement these requirements.
- To support the adoption of nationwide cybersecurity standards and tools to protect the U.S. power grid from Chinese state-backed cyber actors, Congress should:
  - Require the Federal Energy Regulatory Commission (FERC), in consultation with the Secretary of Energy, the North American Electric Reliability Corporation, the Electricity Subsector Coordinating Council, and the National Association of Regulatory Utility Commissioners, to conduct a study and report on transmission and distribution utilities' adoption of minimum cybersecurity standards established pursuant to National Security Memorandum 22 or existing mandatory FERC requirements.

- Direct the U.S. Department of Energy to further authorize and fund projects at the National Laboratories to produce digital twins (virtual replicas of physical systems) for the power grid, leverage artificial intelligence to detect and patch vulnerabilities across the grid, and incorporate digital twins and artificial intelligence into cybersecurity simulations and exercises.
- Require the National Laboratories, U.S. Department of Justice, and Federal Bureau of Investigation to issue a joint report and briefing to Congress on known cybersecurity threats within the United States related to energy critical infrastructure.

Appendix I: Electric Power Systems

Electric power systems broadly consist of five stages: power generation, storage, transmission, distribution, and consumption (see Figure 9).* Most primary energy in the United States is consumed directly by end users in the form of petroleum-based fuel for transportation and petroleum and natural gas for industry.† [277] About one-third of U.S. primary energy is used for electric power generation and flows through the power system to residential, commercial, and industrial end users.‡ [278] The power generation stage converts primary energy sources like natural gas, nuclear, coal, and wind into electricity.[279] This electricity can be stored in an energy storage system (e.g., batteries) for later use or sent long distances through the bulk power transmission system to substations.[280] Those substations then distribute power to end users.[281] Electricity can also be produced by distributed generators—end users that generate their own electricity—such as when a home's rooftop solar panels generate electricity consumed by that household or send electricity into the power system.[282]

Figure 9: Basic Elements of the Power System



Note: 161 kV and 115 kV transmission voltages and 46 kV, 34.5 kV, 23 kV, and other distribution voltages exist. U.S. Department of Energy, *Grid Engineering Practices and Standards: Defining Distribution, Sub-Transmission, Transmission, and the Bulk System for Interconnection*, August 2, 2023, 8.

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*This breakdown excludes the extraction and refining of fossil fuels used for power generation. Some schemas combine generation and storage as well as distribution and consumption.

†Primary energy refers to energy sources in their first usable state after extraction from nature (i.e., petroleum, natural gas, renewables, nuclear, and coal). Morgan Smith, "How Is Primary Energy Defined and Used?" *Congressional Research Service* (Report No. R48270), November 19, 2024, 1, 4.

‡While roughly one-third of U.S. primary energy is used to generate electricity, due to energy losses in each stage of the power system, electricity only makes up roughly one-fifth of U.S. final energy consumption. U.S. Energy Information Administration, *U.S. Energy Consumption by Source and Sector, 2024*, April 2025.

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