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Reshore, Reroute, Rebalance

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Center for Strategic & International Studies
1616 Rhode Island Avenue, NW
Washington, DC 20036
202-887-0200 | www.csis.org

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Executive Summary

Clean energy technologies are no longer niche: they already account for hundreds of billions of dollars in investment and consumer spending, and they are slated to grow exponentially. BloombergNEF estimates that companies and consumers spent over $500 billion on the energy transition in 2020, double the level in 2013.[1] The International Energy Agency (IEA) put investment into clean energy at over $600 billion for several years in a row (before a modest dip expected for 2020 due to Covid-19).[2] In a scenario where the world meets its goals under the Paris Agreement, investment in energy might reach $3.2 trillion a year, of which $2.6 trillion will be directed to low-carbon energy sources, a nearly threefold increase relative to investment from 2015 to 2019.[3] These are vast sums of money that promise to rearrange the geopolitics of industrial competition and energy security.

By late 2020, 126 countries had committed to, announced, or were weighing targets to reach net-zero greenhouse gas (GHG) emissions by 2050.[4] To achieve these goals, states are likely to do far more to reshape industrial sectors, compressing in a few years a process that normally takes decades. They will also compete for investment dollars and jobs to shore up political support for growing climate ambitions. The greater the need for domestic political benefit from clean energy policy, the larger the chance for protectionist or mercantilist behavior among countries.

As the scale of deployment increases, so does the need to think strategically about this system—namely its opportunities and potential vulnerabilities, especially from a geopolitical perspective.

Global supply chains have been instrumental in lowering the cost of technologies such as solar photovoltaics (PV), wind, and batteries for electric vehicles (EVs).[5] These supply chains emerged in part organically, where legacy industrial suppliers saw opportunities to expand into new sectors, and in part due to government action that created demand and led some countries to encourage firms to manufacture products for domestic production and export.

Since its start in the 2000s, the trade in renewable energy products has been contested as countries challenged each other over subsidies or preferential treatment for local firms.[6] These trade skirmishes did not slow the deployment of renewable energy, which was enabled by cost declines that offset whatever friction emerged in the system. But trade conflicts still shaped these industries, especially solar PV, where tariff battles between the United States and China accelerated a buildup in manufacturing capacity in Southeast Asia to evade U.S. tariffs and helped trigger a shift of polysilicon production from the United States to China. Trade dispute matter even if the overall system manages to find a way around them.

International trade is integral to low-carbon energy—and already sizable.[7] The World Trade Organization put the trade in "solar-energy powered goods and related goods" at $300 billion in 2019.[8] Further exports included $58 billion for hybrid vehicles, $26 billion for battery EVs, and $7 billion for wind energy. In total, that amounts to almost $400 billion in exports. By way of comparison, global exports of iron and steel were just over $400 billion in 2019, while plastics were $615 billion. Even relative to hydrocarbons, the trade in low-carbon energy products is meaningful: the members of the Organization of Petroleum Exporting Countries (OPEC) earned $565 billion exporting petroleum and related products in 2019, while the global liquefied natural gas market (LNG) was $147 billion.[9]

When a commodity crosses borders, countries are bound to think about the kind of vulnerabilities that trade exposes them to. Often, these issues are minor and manageable. But when it comes to strategic commodities, or to the commanding heights of the economy, countries scrutinize their supply chains more carefully, wondering whether bottlenecks or disruptions—intentional or accidental—could pose a threat. They worry about relative competitiveness and who they are dependent on, and they look for ways to be more secure. The world has thought about these problems for decades when it comes to oil and gas. As low-carbon technologies become more dominant, similar concerns are emerging.

Of course, the trade in low-carbon energy differs from the trade in hydrocarbons. The energy security implications of a system based on oil, gas, and coal are not the same as for a system reliant on wind, solar, batteries, biofuels, or hydrogen.[10] A digitalized grid is not the same as the refineries and pipelines of the hydrocarbon era. Trade in commodities with volatile prices is not the same as trade in solar panels or wind turbines. The geography of supply will hinge less on geology and more on industrial might. New technologies will depend on critical minerals for which production is now rising. The energy system of the future will look different—but enough similarities will persist for old strategies to be adapted and repurposed.

China has emerged as a critical global supplier for solar PV, as a powerful force in parts of the lithium-ion battery supply chain, and as a major producer, if not exporter, of wind turbines. China also produces many of the nuts and bolts that are used in electricity grids around the world, including in the United States. The deteriorating relationship between China and the United States has thus added further impetus for thinking about supply chains for clean energy to assess how much exposure to China the United States can live with, how to manage whatever exposure cannot be avoided, and how to build systems that, over time, reduce the threats of that exposure for the United States.

Threats can be exaggerated, especially in the current geopolitical context. Governments regularly screen foreign investments in strategic sectors, and the United States has tightened some of the rules for foreign investments with an eye on China, even if the rationale for this tightening was broad and general rather than based on specific vulnerabilities. There was also an effort by the Trump administration to push China out of the supply chain for the bulk power system (BPS), due to the belief that China's presence constituted a security threat. In such an environment defined by mistrust, it is critical to articulate the threat as clearly as possible and craft a response that is targeted and realistic (i.e., not call for an immediate prohibition of a broad set of goods, as the Trump administration did in the bulk power sector).

The United States can apply some of the mental models, tools, and institutions used for conventional energy sources to think about supply chains in clean energy—and grow its economy and boost its national security in doing so. The markets are different, of course, but the experience of the past five decades dealing with energy security yields insights that are relevant for low-carbon energy technologies.

In the aftermath of the 1973 oil embargo, the United States made "energy independence" a national project—it was never the only strategy that the United States pursued, but it became a yardstick for measuring progress and an endpoint to chase, however elusive the target actually was. There is a similar thrust toward reshoring today—a call to reorient supply chains away from China and back to the United States or, at least, to countries that are friendly toward the United States. But reshoring takes time and is not always entirely desirable. Specialization and trade have been critical for clean energy technologies, and to prevent this trade could be costly and short-sighted at a time when the world needs to deploy more low-carbon energy technologies. A balance is needed.

In designing a strategy, the United States should be guided by three core propositions. First, the potential messiness of the energy transition cannot be an excuse to delay or to slow down that transition. The risk of a world with unmitigated climate impacts far outweighs the geopolitical difficulties of managing the transition. Second, the strategic threats and vulnerabilities of the transition to a low-carbon world must still be taken seriously. The need to combat climate change has to be balanced against legitimate concerns that threaten national security and prosperity. It needs to recognize that failure to address these issues could have negative repercussions for the country, global stability, and deep decarbonization efforts writ large. Third, decoupling from China in low-carbon energy is impossible today; in the future, it is improbable and likely expensive. Given these realities, the United States needs a grand strategy for the geopolitics and geoeconomics of the energy transition—recognizing that there is no single policy or strategy that can meet the diversity of U.S. needs.

The United States can apply some of the mental models, tools, and institutions used for conventional energy sources to think about supply chains in clean energy—and grow its economy and boost its national security in doing so.

Devising an overall approach to manage these challenges should look and feel familiar. Several strategies that the United States and others pursued in relation to oil and natural gas could apply to increase the resilience and security of clean energy supply chains. To manage the geopolitics of oil and gas, countries created international institutions to increase transparency, coordinate, reduce conflict, and manage disruptions. They set rules for what behavior is acceptable, used interdependence to check adversaries, nurtured alternative suppliers to create regional diversification, and used diplomacy and even force to shape the environment in which the trade of oil and gas took place. There is no need to copy this history, but there is a rich experience from which to extract useful lessons, including ideas to avoid.

The best defense for the United States, however, is offense: become a major producer and manufacturer of clean energy in existing and emerging technologies. Above all, this requires policies that incentivize the deployment of clean energy—it all depends on having a major domestic market to serve. It requires strategic investment in innovation, especially in areas not yet captured by competitors. It requires planning to avoid the trade skirmishes of the past, or at least to reduce how disruptive they are, to ensure that supply-side policies to nurture manufacturing are not undercut by dumping or other predatory policies. It requires taking the time and focus to create the ecosystems that are conducive to manufacturing, leveraging existing or legacy capabilities, and nurturing clusters that can grow to capture the technologies of the future—all the while avoiding the pitfalls of picking winners and protecting uncompetitive firms. In short: it requires smart green industrial policy.

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1

Growing Industrial Competition

Government climate strategies are changing as climate politics increasingly follow the logic of "green industrial policy."[11] Countries have implemented industrial policies in pursuing energy diversification and security for decades, but only recently have these ideas been applied to the climate crisis. Targeted support for "green" industries has been around since at least the late 1980s, accelerated during and after the financial crisis of 2009, and seems likely to accelerate further in response to the Covid-19 crisis.

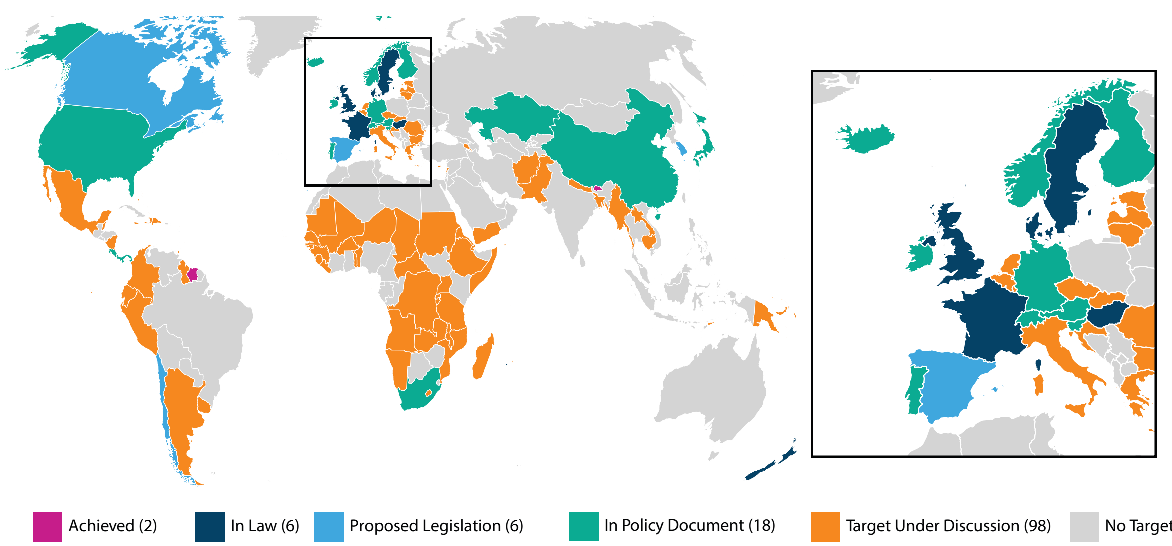
This paradigm is distinct from past efforts in that it is more ambitious, not only in its emissions goals but in its broad scope of policy priorities, such as job creation and technological competitiveness.[12] It is more focused on the wholesale transformation of the economy by actively promoting specific industries that are consistent with deep decarbonization goals. In promoting one sector over another, green industrial strategy necessarily reflects a philosophical shift in government intervention that includes greater public-private collaboration, experimentation, and risk-taking. Within this context, the policy instruments used to implement climate policy are shifting from a regulatory approach of pollution minimization to an industrial strategy approach of coordinated public investment, technological development, niche market creation, job growth, and trade protection.

Rising Climate Ambition Backed by Plans for Economy-Wide Transformations

Over the last 10 years, many of the world's largest emitters have dramatically increased their climate policy ambitions and, with it, the scope of government intervention in the name of climate change. In 2015, nearly 200 countries agreed to a collective goal to "to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels." As countries have announced policies to reach this goal, estimates of temperature increases by the end of the century have fallen by 0.7 degrees Celsius.[13] Today, 126 countries have announced or formally adopted a target of reaching net-zero GHG emissions by 2050, even if only six countries have passed such targets into law.[14] At the United Nations Conference of Parties (COP26) in November, it is expected that many countries will fill out these 2050 pledges with 2030 sectoral targets in their updated Nationally Determined Contributions.

To make the case for such ambition, policymakers have had to shift the framing and manage the sequencing of climate policies.[15] Since at least the early 2000s, climate policy has moved from a focus on pollution minimization to using clean energy policy to create new economic opportunity.[16] Some of the clearest examples were the investments in clean energy as a source of economic growth and recovery in the wake of the global financial crisis. In response to the financial collapse, nearly half a trillion dollars in green investment was included in countries' stimulus plans, or about 15 percent of the total, marking a significant increase in the scale of green industrial policies.[17] Significantly, instead of framing climate action as a costly sacrifice in exchange for environmental benefits, advocates and

130 Countries Have Adopted or Are Discussing a Net Zero Target



Source: "Net Zero Tracker," Energy & Climate Intelligence Unit, 2021, eciu.net/netzerotracker.

Note: Net zero targets differ by target date, type of emissions covered, and other factors. For more information, visit eciu.net/netzerotracker policymakers began really emphasizing the co-benefits of climate policy, particularly job creation and industrial competitiveness. Politically, providing concentrated benefits to a few well-organized industries, such as renewable energy firms through feed-in-tariffs and tax credits, has expanded the coalition of interests in favor of climate action, driving further green industrial policies over time.[18]

Most recently, this green industrial strategy framing has been seemingly ubiquitous in advocacy for Covid-19 stimulus and recovery packages. The International Monetary Fund, World Bank, G20, and others have all called for various forms of a "green, inclusive, and resilient recovery" to the crisis.[19] However, real-world dollars committed to a green recovery have been less forthcoming. Outside of Europe, few countries have dedicated significant funds to green investments, with only seven countries—Spain, Denmark, France, the United Kingdom, Germany, Norway, and Finland—committing more than 1 percent of GDP.[20] Such assessments may be premature, however, with many policymakers, including the new Biden administration, separating the response to Covid-19 into separate "rescue" and "recovery" plans, indicating that green recovery is still yet to come. The American Jobs Plan, announced by the Biden administration in late March 2021 and including over $1 trillion in climate-related spending, could very well mark this turning point from rescue to green recovery.[21]

Sectoral Roadmaps

Embedded in these green recovery plans, and the green industrial policy paradigm more broadly, is an emphasis on creating new markets, inventing new technologies, and restructuring entire economies.[22] This is a hallmark of industrial strategy which aims to alter "the structure of an economy, encouraging resources to move into particular sectors that are perceived as desirable."[23] Traditional industrial policies have typically promoted manufacturing in export-oriented industries, such as auto or aviation manufacturing, which have significant productivity and trade spillovers. Green industries are desirable not only for addressing these structural economic issues and securing a better position in global production and trade networks but also in systematically decarbonizing economies and winning political support for further climate action.

This approach is visible in the proliferation of strategic planning documents and "roadmaps" that lay out how this sectoral restructuring will take place. These include the European Commission's "European Green Deal," South Korea's "Green New Deal," China's list of "Strategic Emerging Sectors," and, arguably, Biden's "Build Back Better" agenda. The key feature in all these roadmaps is the delineation of priority or strategic sectors. Typically, these sectors include renewable electricity, carbon capture and storage, EVs (both private and commercial), low-carbon hydrogen, energy-intensive industrial processes, maritime shipping, and commercial aviation.

Consider, for example, the United Kingdom's "Industrial Strategy: Building a Britain fit for the future." This broad economic agenda was subsequently bolstered by the Ten Point Plan for a Green Industrial Revolution, which outlines 10 priority sectors based not only on their emissions reduction benefits but job growth and investment opportunities as well.[24] Unlike the laissez-faire approach of Thatcherism, Britain's modern industrial strategy includes a range of planning mechanisms, including identifying policy goals, strategic sectors, and an accountability framework that brings private sector stakeholders deep into the policy process. Since the early 1990s, the United Kingdom has pursued various forms of green industrial policy in offshore wind to great success.[25] The distinguishing feature of its Ten Point Plan is that it wants to build on this success while replicating it in a range of other industries, such as low-carbon hydrogen, EVs, green ships, and more.

Deeper Public and Private Sector Collaboration

The decarbonization of private transport and manufacturing of EVs is shaping up as a central source of competitive tension between rival producers and is the focus of many countries' 2030 strategies. China has been especially aggressive in its EV industrial strategy over the last decade, growing from a market of just 5,000 cars in 2011 to over 1 million cars in 2019, accounting for half of global market share that year.[26] Moreover, China has strategically built an early-mover advantage in every component of the upstream supply chain for battery technologies, giving it a competitive advantage in moments of supply shortages and leverage in times of geopolitical tension.[27] Similarly, Europe is aggressively pursuing a vertical strategy of support across all facets of the EV supply chain, from R&D to critical minerals production to battery and EV manufacturing, including through its European Battery Alliance initiative.[28]

The European Battery Alliance brings together public and private stakeholders to develop a sustainable battery value chain in Europe and is another example of the ways in which public and private actors are collaborating in dedicated green industrial policy institutions. A key feature of today's industrial policy is that it is "much less about top-down incentives and much more about establishing a sustained collaboration between the public and private sectors."[29] Public-private collaboration forums and institutions can also help overcome coordination failures, improve knowledge-sharing, and inform planning processes. Some countries have a long history with this approach, such as Germany, whose manufacturing industry benefits from close collaboration with research institutes, local credit unions, and vocational training institutes.[30] Under the Obama administration, the United States explicitly modelled its approach on the German Fraunhofer Institutes, creating a network of advanced manufacturing institutes across the country, each a cluster of firms, universities, and laboratories developing specific technologies.[31]

Hybrid Institutions

Another example of public-private hybrid institutions playing a key role in green industrial policy is development banks, which can help direct credit and mobilize private investment in priority sectors of the green economy. Development banks are state-owned or state-run financial institutions with a development mandate, and in recent years they have been revived as both a development tool and an arm of green industrial policy.[32] This resurgence includes both the number of dedicated green or climate banks, who can only invest in climate-related projects, as well as the share of national development banks' portfolios earmarked for green industries and technologies.[33] Until 2018, development banks were the single largest global investors in green finance, and they continue to provide the bulk of concessional loans and low-cost project debt, reflecting their higher risk tolerance and development mandate.[34] Both varieties, such as Germany's wide-ranging KfW and Australia's climate-specific Clean Energy Finance Corporation, have proven effective catalysts of private investment into low-carbon projects while enabling private sector learning and building trust in nascent or otherwise risky green sectors.[35]

The development bank model is also attractive for the ways in which it mitigates political risks. For example, a dedicated financial institution operating with all the resources and capabilities of a private firm and the mandate of a public entity is in a much better position to "pick winners." Not only have they been shown to be more efficient allocators of capital, but they help hide desirable losses in a portfolio approach from the public eye, avoiding situations such as the Solyndra controversy of 2011.[36] A development or green bank operating under conditions of political independence and corporate accountability is less vulnerable to accusations of political manipulation, corruption, or incompetence. Independent institutions are also more stable through fluctuating political cycles. For example, the world's largest dedicated green bank by capitalization, Australia's Clean Energy Finance Corporation, has grown in size and scope even under a conservative government that has tried to dismantle it, limit its remit, and otherwise roll back climate policies and ambition.[37]

Countries are also rediscovering institutional structures in innovation and technology policy that move beyond traditional modes of publicly funded research. In contrast to the traditional "pipeline" model of innovation—where government funds basic science which private industry then picks up and turns into a developed product—modern innovation agencies are more likely to adopt a "mission-oriented" model of public-private collaboration and targeted funding, akin to the approach of the space race or the Manhattan Project.[38] For decades, this approach was limited to the defense industry. However, as climate change has grown in political salience and potential impact, the lessons of mission-oriented innovation are being applied as a tool of green industrial policy. The most striking example is the Advanced Research Projects Agency-Energy (ARPA-E) in the United States, modelled after DARPA in the Pentagon. ARPA-E has been so successful that the new Biden administration has announced it will establish a second, climate version, ARPA-C. The United Kingdom is currently debating the merits of a "British ARPA," while the European Union's Horizon 2020 scheme explicitly adopts a mission-oriented approach in its mandate and institutional structure.[39]

Mixing the Right Incentives

The focus on R&D funding and innovation institutions reflects the increased focus on the supply side of green industrial policies, complementing the demand-side instruments, such as carbon prices or gas taxes, that tend to feature more prominently in classic environmental policy. While there are certainly overlaps in instrument type, such as targets, regulation, and public investment, green industrial policies vary more in the breadth of policy goals and mix of overlapping tools.[40] As political scientist Jonas Meckling notes, "put simply, the formula for green industrial policy is 'public investment + standards' compared to 'pricing + standards' in environmental policy."[41] Countries are more likely to combine policies that invest in a sizable, stable local market with incentives for localizing parts of the production chain, as well as innovation in new low-carbon technologies.[42]

The history of renewable energy illustrates how this approach developed. In the earliest phases of solar PV technology, the United States and Japan implemented a series of supply-push innovation policies, such as R&D funding and subsidies for demonstration projects but failed to build a sizable local market.[43] Germany's grid feed-in law created the first significant market for the technology but included few complementary supply-push policies. As a result, Germany saw its share of solar manufacturing fall from 25 percent in 2008 to just 5 percent only three years later.[44] China, on the other hand, gradually shifted from a supply reaction to a more coordinated suite of green industrial policies throughout the solar value chain and today dominates solar manufacturing in almost every facet of the global supply chain.[45]

Focus on Workers and Communities

The green industrial policy framework also overlaps with notions of providing a "just transition" and sources of "good jobs," tying various employment and labor market policies to climate change.[46] This includes creating new jobs and occupations but also smoothing the adjustment of the labor market to a greener economy. A growing body of literature is developing around reskilling and education strategies, such that a domestic workforce formerly skilled in a carbon-intensive industry has the capacity to work in newer low-carbon industries. The European Union, for example, has included a Just Transition Mechanism in its green deal strategy.[47] This €40 billion ($48 billion) fund can be accessed by member countries to support workers' transitioning from carbon-intensive sectors, such as coal mining, to green industries. Generally, though, labor market policies, including workforce development programs and labor standards, cut across sectors and are not targeted at green industries, but they can still play an important role in facilitating green job creation.[48]

A Turn toward Green Industrial Policy Is Not without Risks (and Opportunities)

It is not yet clear how significant the green industrial policy paradigm will be, or what risks and opportunities will manifest. More countries are clearly adopting the language of green growth and win-win climate policy, but few of these have put significant funding or institutional heft behind the rhetoric. Others are implementing pieces of green industrial strategy but without the overarching vision to guide next steps or take advantage of policy synergies. On the other hand, as the language of green industrial policy becomes more ubiquitous and if early movers demonstrate examples of successful implementation, more countries are likely to emulate elements of this strategy.[49] There is also emerging evidence that the adoption of more traditional climate policies, such as an emissions target, encourages the adoption of green industrial policies as the only realistic way of restructuring a low-carbon economy.[50]

Even if countries were to increasingly adopt green industrial policies, there is little guarantee that they would be permanent. Current efforts could be short-lived political ploys in the face of entrenched opposition, building confidence in climate action before reverting to something more globally interconnected and pollution-focused. The most difficult phase of any technology transition is the emergence of a novel technology in the face of incumbency bias. Therefore, as green technologies capture a greater share of respective markets and political resistance to climate action erodes, it may no longer be necessary to support these industries through an industrial strategy framework.

Successful green industrial policies, on the other hand, could further shift the politics of climate action, expanding the political coalition in favor of aggressive decarbonization. Climate policies to date have been hampered by the political and economic hurdles posed by legacy carbon-intensive industries, the power of which will likely decline as the energy transition progresses. Traditional climate policies, such as carbon prices, have often provoked a political backlash to climate action, whereas green industrial policies are more likely to generate a positive feedback loop of gathering political momentum.[51] Of countries that have established a carbon price, the majority first used green industrial policies, such as subsidies or capital grants, to create a local renewable energy industry or low-carbon vehicle market before implementing the pricing mechanism.[52]

Green industrial policies derive their political success from offering concentrated benefits to political constituencies, including voters, industries, and other interest groups, and growing those constituencies over time through economic support.[53] Case study evidence of growing climate policy stringency in California and Germany, for example, shows how these jurisdictions began with sector-specific instruments, waiting for greater political support before implementing broader climate policies.[54] If policymakers can deliver on promises of well-paying "green jobs" for voters and continue providing subsidies or protectionism for green industries, the coalition calling for yet more government intervention will continue to grow. Countries are also experimenting with ways of tying climate actions to other political priorities, such as reducing inequality, addressing systemic racism, rebuilding a manufacturing sector, or competing with geopolitical rivals, potentially building wider and deeper political support. While it is too early to widely evaluate this approach, early political science experiments and polling data in the United States indicate that this may further broaden the political coalition in favor of climate action and green industrial policies.[55]

Further, the economic case for green industrial policy is likely to grow as the costs of low-carbon technologies continue to plummet. The price of solar energy has fallen 82 percent in the last 10 years, onshore wind has declined by around 40 percent, and lithium-ion batteries have fallen by 97 percent since first becoming commercially available in 1991.[56] As these technologies become more competitive with high-carbon incumbents, the potential economic and political gains become more obvious, creating a "green race" for jobs and investment.[57] More countries competing to build local green industries could drive down costs, creating more incentives to pursue such policies.[58]

This expansion of green industrial policies will of course bring both risks and opportunities. The greatest risk is that countries do too little on climate rather than too much, ushering in an era of disastrous climate impacts and instability. Though scientific assessments of climate impacts have had notoriously little impact on public policy, the simple fact is that the best assessments suggest meeting the Paris climate goals will require almost unprecedented levels of state intervention. A future without green industrial policies is likely one that misses these targets by a wide margin. As the International Panel on Climate Change noted in the Special Report on Global Warming of 1.5°C, "limiting global warming to 1.5°C . . . would require rapid and far-reaching transitions . . .[that] are unprecedented in terms of scale."[59]

It is also important to recognize that developed countries turned away from an industrial strategy approach decades ago for a reason, and in dusting off the industrial policy playbook, policymakers will need to be aware of pitfalls and trade-offs. In particular, industrial policy is often seen as being "synonymous with white elephants [and] rent-seeking," creating problems of inefficient capital allocation and political corruption.[60] While such characterizations of past industrial strategies are largely overblown, there will doubtless be clear and growing incentives for governments to engage in "picking winners" or protecting national champions in a world of widespread green industrial policy.[61] In China, for example, industrial institutions have long been plagued by inefficient government guarantees, widespread corruption, and the creation of unstable investment bubbles.[62] Not only can this undermine the effectiveness of green industrial policies in achieving both their climate and economic goals, but it can also erode the legitimacy of such a strategy in the public eye.

Another risk is that green industrial policies divert the gains from globalization that have helped drive down the costs of clean energy technologies as countries turn inward or seek substitutes for imports more efficiently produced elsewhere. Cost declines in tradable goods are greatest when production shifts to countries with a comparative advantage in a particular component of the supply chain. As countries move for political reasons into sectors in which they do not have such an advantage, the costs of such goods could plateau, or even increase.

There is already a growing turn toward protectionism and isolationism in green industrial policy, for example, through the use of local-content rules. More popular in developing than developed countries, these policies require that a minimum level of goods and services be bought or manufactured locally. For example, Brazil, India, and South Africa have all implemented versions of these local content rules in renewable energy, though none were implemented as part of a broader green industrial policy vision. As such, these policies have had little success in creating additional manufacturing capacity and instead have contributed to increasing project costs.[63] Other examples include local content requirements in China's auto manufacturing industry and a short-lived scheme in two Canadian provinces to promote wind turbine manufacturing. Most recently, as the first step in his broader "Made in America" plan, President Biden signed an executive order to strengthen the Buy American Act, which gives preference to domestic manufacturers.[64]

Another potentially protectionist measure is the "carbon border tax" or "border adjustment mechanism." This would apply tariffs to imports based on their carbon content or, alternatively, the ambition of a country's climate policies. Europe is furthest along in planning such an instrument, with an official proposal expected in a matter of months. President Biden has also indicated that he will impose "fees" on low-ambition countries, and the U.S. Office of the Trade Representative recently announced it was considering carbon border adjustments.[65] This instrument is seen as particularly important to protecting local heavy industries, such as steel or cement production, which might otherwise suffer from a significant competitive disadvantage in global markets.

However, this does not seem to be a major concern, as discussed further in the section below on potential cost implications. The limited evidence that such gains to trade are at risk is likely outweighed for many countries by the potential benefits of new export opportunities and the long-term terms-of-trade impacts on the economy.[66] Further, the zero-carbon transition will likely change countries' comparative advantages over time, potentially increasing competitiveness and productivity in the bargain.[67]

2

Trade Tensions and Reliance on Chinese Supply Chains

The growing concern about China's dominance in clean energy markets and overreliance on Chinese supply chains is the clearest example of trade and geopolitical issues arising at the nexus of clean energy and industrial policy. Over the past 15 years, the world has deployed at some scale three core low-carbon technologies: solar PV, wind power, and lithium-ion batteries for EVs. The growth in these technologies has been enabled by international trade and global supply chains—exports of these three products were around $400 billion in 2019.[68] As these technologies were first enabled by government support, they were instantly entangled in trade disputes, many of which involved China, as countries tried to counter what they saw as predatory Chinese behavior favoring its own firms. These trade disputes created friction and shaped the trajectory of the market. They also largely failed to prevent China from amassing a commanding position in these technologies, and the country is now a clear leader in solar PV, lithium-ion batters, and, to a lesser extent, in wind power generation. And given China's market share, clean energy technologies were also caught up in the trade war between the United States and China that emerged during the Trump presidency. These interlocking dynamics—trade disputes and excess reliance on China—set the backdrop for how these technologies were scaled and the kind of challenges that come from their continued expansion.

China's Market Share in Clean Energy

The technology used in solar PV was first developed in the United States and then was supported heavily by state subsidies in Germany starting in 2004.[69] Toward the end of the decade, China began to ramp production of PV cells and modules, but still secured the primary feedstock – polysilicon—from abroad. By the early 2010s, however, Chinese manufacturers began to expand vertically up the supply chain. China started to account for an ever-increasing share of new polysilicon factories, eventually eclipsing other producers and forcing many of them into bankruptcy.[70] This shift was contested as several countries launched trade investigations and imposed tariffs on Chinese cells and modules, although these failed to stop China. Though these barriers forced Chinese producers to move manufacturing facilities to Southeast Asia as a way to bypass tariffs, China still accrues the vast majority of the value of a solar module imported into the United States from Southeast Asia today.[71]

The Chinese focus on lithium-ion batteries and EVs came later, as the country was a marginal market for these technologies when they were taking off in advanced economies. China has leveraged its massive market to establish itself across the battery value chain from refining onwards, even if most of the mining in critical raw materials happens elsewhere. (This is especially true for lithium and cobalt but not nickel.) In the final stages of battery production, however, the market becomes more diverse, given the legacy production capabilities in South Korea and Japan for battery cells and new facilities in Europe and the United States for battery packs. But cell manufacturing remains concentrated in China. As such, the value split for a battery depends very much on who is supplying that battery—with much of the value accruing to the United States and a smaller share to China.[72]

The Chinese were never able to amass a commanding position in wind, in part because high transportation costs favor manufacturing close to where the market is and in part because firms in North America and Europe were quick to expand in this space and consolidate their position. Almost half of wind turbine nacelles manufacturers are domiciled in China, but the Chinese mainly produce for the Chinese market, unlike in other products where they are major exporters of either intermediate or final products. For a typical wind turbine installed in the United States, more than half the value accrues to the United States, with only a modest amount (8 percent) going to China.[73]

How Trade Disputes with China Shaped Clean Energy

Government policies to support renewable energy deployment often clashed with a trade regime that favors open access and non-discrimination. The United States routinely challenged elements of Chinese industrial policy that subsidized Chinese manufacturers who were competing in international markets, making the U.S.-China relationship an active theater in the clean energy trade wars of the 2010s. Each area of disagreement led to another as a tit-for-tat quarrel spread to more products and escalated in intensity. These disputes, and the underlying government incentives that they responded to, reshaped clean energy supply chains.

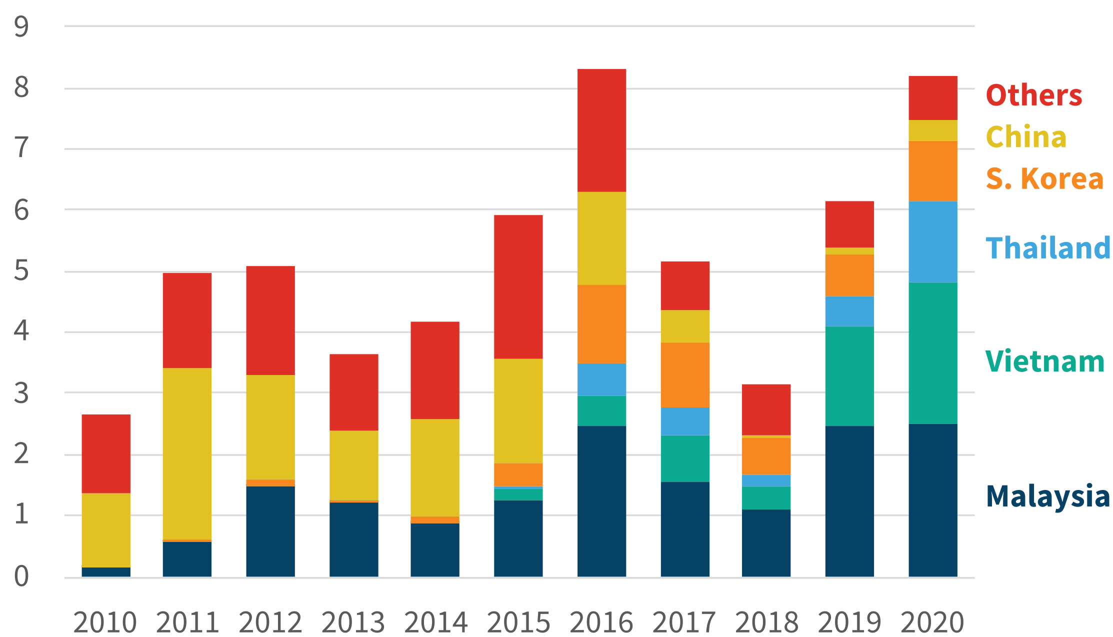
The first trade dispute related to wind or solar came in December 2010 when the United States challenged China's Wind Power Equipment Fund for making grants contingent on parts and components being made in China, thus discriminating against imported goods. (Following consultations, China cancelled the program in February 2011.[74]) By 2011, the United States had launched an investigation against crystalline silicon PV cells from China, issuing antidumping and countervailing duties in December 2011.[75] Just as that dispute was wrapping up, the United States launched an investigation in January 2012 into Chinese and Vietnamese utility-scale wind towers, leading to antidumping and countervailing duties against China in February 2013 (Vietnam was targeted only for antidumping duties).[76] By August 2014, the United States was once again looking into crystalline silicon PV cells from China and Taiwan, issuing countervailing and antidumping duties against products from China (and antidumping orders against Taiwan).[77]

China, for its part, retaliated. In 2014, it imposed antidumping tariffs and countervailing duties on U.S. polysilicon producers, leading U.S. polysilicon production to fall by half between 2014 and 2018 as producers struggled to find alternative outlets for their output.[78] China slowly came to dominate global polysilicon production—from producing effectively nothing in 2010 to having built a commanding position in 2020, with much of the production located in Xinjiang (more on that later).[79] But more importantly, Chinese manufacturers shifted solar manufacturing overseas, especially to Southeast Asia. In 2011, before the first round of tariffs, almost 60 percent of solar PV modules and over 40 percent of cells came from China; by 2018, those figures had shrunk to effectively zero.[80] Instead, over 78 percent of modules imported into the United States in 2020 came from Vietnam and Malaysia, while imports of cells came mostly from South Korea (but are minor relative to module imports, at $474 million in 2020 versus $7.7 billion for modules).[81]

The U.S. solar industry has shrunk in relative and absolute terms. In 2004, the United States shipped 13 percent of the world's solar PV modules; by 2017, that number was less than 1 percent (and is still hovering around there).[82] The story varied across the value chain: wafer production ended in 2015, cell production has gone up and down, inverter production kept rising but then fell after 2017, and module production jumped in 2019 after years of stability. These changes can be summed up in this statistic:

U.S. Imports of Solar Cells and Modules by Country of Origin

billion dollars



Source: U.S. International Trade Commission. Note: Data for modules refer to harmonized system (HS) codes: 8541406015, 8541406020, 8541406035; for cells, codes 8541406025, 8541406030 based on David Feldman and Robert Margolis, Q2/Q3 2020 Solar Industry Update, National Renewable Energy Laboratory (NREL/PR-6A20-78625), December 8, 2020.

in 2010, the solar PV manufacturing industry in the United States earned more in revenue than the deployment industry; by 2019, the revenues from deployment were 10 times higher than the revenues from manufacturing.[83] What was, a decade ago, a story of both manufacturing and deployment was now largely a deployment story based on imported goods.

Trade Conflicts during the Trump Presidency

The tariff actions taken by the Trump presidency merely reinforced this gap and further reduced ties between the United States and China in clean energy. In January 2018, the Trump administration put tariffs on crystalline silicon PV cells and modules. (Cells were given an exemption for the first 2.5 gigawatts, while modules were hit without such a carve-out.) The tariffs were levied under Section 201 of the U.S. Trade Act of 1974, which allows for trade remedies when "increased imports are a substantial cause of serious injury to domestic producers," an unusual route last used by the Bush administration in 2002.[84]

U.S. shipments of solar PV modules, which include imports, declined by 27 percent in 2018, but they had also declined in 2017, before the tariffs were put in place, and then more than doubled in 2019, even though the tariffs were still in place. This offers evidence of how difficult it is to attribute year-to-year shifts to trade policy when it comes to a nascent and rapidly evolving market.[85] Trade flows were also affected by a tariff exemption for bifacial panels, which prompted a surge and later a contraction in imports during the period when the exemption was in place, though the measure was later revoked.[86]

The solar industry was also affected by the escalation in trade tensions between the United States and China that began in late 2017 and lasted throughout the Trump presidency.[87] The tariffs on steel and aluminum imposed in 2018 were expected, at the time, to raise costs for solar PV by a modest amount (up to 5 percent).[88] And solar products were caught up in the various rounds of tariff increases that characterized the trade war between China and the United States. By one estimate published in December 2020, imports from China were subject to a cumulative tariff burden that ranged from 50 to 60 percent, and those tariffs are one of many factors why the average price for modules in the United States is significantly higher than it is in other parts of the world.[89]

More recently, the solar industry has been shaken by its reliance on the Xinjiang region for polysilicon, linking the industry to an area where there are acute human rights concerns around forced labor and forced assimilation, actions that the United States now calls "genocide and crimes against humanity."[90] So far, the United States has mostly responded by targeting a few entities and individuals under the Global Magnitsky Act without targeting commodities or value chains—although these could yet be hit. This is just another example of the complex chain reactions that have emerged in response to trade sanctions and counter-responses: polysilicon production in Xinjiang took off after China imposed tariffs on U.S. polysilicon in response to earlier U.S. tariffs on crystalline silicon PV cells from China, even though China was heavily investing upstream into polysilicon already. And so an initial dispute about cheap loans and subsidies by the Chinese government is morphing years later into a dispute about supply chains and human rights abuses.

While the relationship with China has been the most contentious, it is hardly the only theater for disputes over clean energy. In February 2013, the United States challenged India for provisions in its

National Solar Mission program that favored domestic manufacturers. The World Trade Organization (WTO) ruled in favor of the United States in 2016, but by 2017, the United States claimed that India had failed to abide by the ruling, with the dispute going to arbitration.[91] India, for its part, filed a case in February 2016 against eight U.S. states for domestic content requirements in the renewable energy sector. A WTO panel ruled in favor of India, but the United States has appealed the decision.[92] And these are just some of the many disputes involving solar energy with Canada, Japan, Korea, and the European Union having been involved either as a complainant or a respondent.[93]

Solar was one of the industries most directly impacted by trade disputes, but it was not the only one. After all, the first challenge in the 2010s came from the wind sector and the United States challenging Chinese local content rules. In 2013, the United States imposed tariffs on utility-scale wind towers from China and Vietnam. More recently, in 2020, the United States launched an investigation against utility-scale wind towers from India, Malaysia, and Spain, with a preliminary determination supporting the claim that products have been subsidized and sold in the United States for less than fair value.[94]

Batteries have been less directly implicated in trade disputes, at least in the context of subsidies, local content rules, and national security grounds, which are the legal foundations for many of the disputes described above. A 2019 dispute over lithium-ion batteries used in EVs has threatened to disrupt the auto market in the United States and sent ripples through the market at the time. However, this is a dispute over intellectual property rules—an example of more traditional trade issues affecting the renewable energy sector as its share of the global economy grows—and the dispute was settled thanks to the intermediation of the Biden administration.[95]

The High Stakes of Continued Trade Tensions

In normal times, these trade disputes would be a nuisance that is otherwise manageable. Certainly, the steep reduction in costs for renewable energy has created a momentum whereby trade barriers increase costs, but these premiums disappear swiftly as the underlying cost keeps declining—in this context, trade barriers have acted a retardant force more than a blocking one. But the institutional weakness of the WTO has also meant that disputes linger for years, and the standard practice, whereby countries retaliate against each other, has created a dangerous dynamic where tit-for-tat actions lead to a vicious cycle that becomes harder to untangle.

In a broader sense, however, the trade regime will have to fight against a strong current that is pushing the United States and China apart. During the Trump presidency, the relationship with China became more acrimonious, and disputes spread to several domains. The United States tightened rules for foreign investment and exports of sensitive technologies; targeted major Chinese tech companies such as Huawei, TikTok, and WeChat; strengthened oversight on federal-funded researchers and their interactions with foreign governments; issued warnings against Chinese companies in U.S. financial markets and exchanges; and sanctioned individuals, companies, and government entities that engage in human rights abuses or military operations that threaten peace, such as in the South China Sea.[96]

The broader strategic environment means that even if individual trade disputes might wind down or be superseded by market forces, there is an underlying current that will persist. This will generate new disputes, fuel the distrust that leads U.S. policymakers to eschew reliance on Chinese supply chains, and lead to increased rhetoric and action on the need to reshore supply chains. Just as import dependence on oil created a recurring push for boosting domestic production in the name of "energy independence," the perceived vulnerability of relying on China for critical products related to both decarbonization and the long-term economic competitiveness of an economy with a material low-carbon industrial sector could provide an impetus for reshaping these supply chains. Of course, there is a difference between the trade in fuels and the trade in manufactured products—there will be no angry motorists if solar panels are no longer imported from China. But the sense of strategic exposure remains, even if it takes a different form. It is against this backdrop that U.S. policy must be conceived and operationalized.

3

Cyber and Other Security Risks to the U.S. Electric Power Infrastructure

The type of energy system required to meet global climate targets will rely more on the electric power system, and that system will come to rely more on distributed energy resources (DERs) for power generation, storage, and flexibility. Therefore, the potential vulnerability of that system will be of even greater importance than it is today. Recently, this heightened concern has begun to manifest itself once again, principally around the role of Chinese equipment and investment.

Protecting the U.S. power system against cyber threats is not a new challenge. It is a challenge that the U.S. government has managed, not solved, as physical systems that power the U.S. economy become increasingly automated and interconnected, and therefore more vulnerable to disruption. In fact, as technologies and their applications constantly evolve, cybersecurity falls in the realm of what is unsolvable but manageable with constant focus and proactive management.

The electric power system in the United States is a highly complex system that entails over 3,000 utility companies, 200,000 miles of high-voltage transmission lines, 55,000 substations, and 5.5 million miles of distribution lines. The system relies on a number of hardware devices and software systems that are globally sourced for electricity generation and delivery. The bulk power system (BPS), which is generally defined as a large interconnected electrical system consisting of an aggregate of generation and transmission facilities, is no exception. The system relies increasingly on operational technology and information technology consisting of numerous pieces of mechanical and automated equipment, ranging from transformers and breakers to smart meters and sensors.

Cyber risks to the electric power system can come from direct attacks aimed at the grid or other critical infrastructure which could impact the operations or security of the grid. Cyberattacks can be aided through exploitation of vulnerabilities in the component supply chains, including insertion of counterfeits, unauthorized production, tampering, theft, and insertion of malicious software and hardware.[97] There is a debate as to whether the growing integration of DERs is a net positive or negative to the U.S. power system's resilience to cyber threats. If they can operate independent of the grid, distributed sources and microgrids, which are generally sited close to the point of consumption, could bring a net resilience benefit when combined with reliable energy storage with capacity large enough to provide multiple days' of supply. If DERs are implemented without industrial-level resiliency requirements, they could add another layer of cybersecurity challenges, as they entail greater spatial distribution of devices and accompanying access points as well as high levels of automation.[98] By the early 2010s, the vulnerability to cyberattacks of the increasingly integrated and automated electric power delivery system had emerged as a top-level concern to U.S. policymakers. The energy sector—including electricity, oil, and natural gas—is one of 16 infrastructure sectors that are designated as critical infrastructure by Presidential Policy Directive-21 (PPD-21), issued in 2013.[99]

Whether intentional or unintentional, damage to certain power equipment, such as high-voltage transformers, can deal an extensive effect on U.S. economic activities. Per the Fixing America's Surface Transportation Act (FAST Act) of 2015, the U.S. Department of Energy (DOE) considered whether to establish a strategic reserve of large, high-voltage transformers. These transformers, which are commonly not manufactured in the United States, are expensive and require a fairly long lead time to manufacture. Ultimately, DOE decided in 2017 that it would support existing industry programs for the sharing of spare transformers, such as the Spare Transformer Equipment Program by the Edison Electric Institute that by then counted over 50 electric utilities as participants.[100]

Managing Potential Threats

Cyber threats can emanate from nearly any state or non-state actor with the requisite capabilities, including domestic actors. China's market position, technical capability, and rising geopolitical rivalry, however, make the country a unique concern to the United States. Chinese cyberattacks have traditionally targeted intellectual property to gain economic advantages (i.e., industrial espionage) or personal identifiable information from businesses and U.S. government agencies to support its intelligence operations. The rising geopolitical rivalry between the United States and China elevates the risk that China would use its cyberattack capabilities to incapacitate the U.S. power system for national security gains.

For example, the 2018 Worldwide Threat Assessment of the U.S. Intelligence Community warned that China, Russia, Iran, and North Korea pose cyber threats to the United States and that they could deploy cyberattacks as a "foreign policy tool outside of military conflict" and cause "localized and temporary disruptions of critical infrastructure."[101] In the 2019 edition, China is seen as the "most active strategic competitor" that presents a growing attack threat to U.S. military and critical infrastructure systems.[102]

Moreover, the Homeland Threat Assessment, published in October 2020, noted that China represents the top threat to U.S. supply chain security, given the sophisticated intelligence and cyber capabilities they can use to infiltrate trusted suppliers and vendors and target equipment and systems, especially through the information and communications technology (ICT) supply chains. The report also acknowledged, however, that China's growing market dominance in key sectors makes it difficult for the United States to source and supply key goods and services that do not depend on Chinese suppliers or investment.[103] BPS and DER components are no exception. Although the specific share of Chinese components in U.S. power sector supply chains is difficult to know, China's strong market position in electric equipment and DERs (e.g., PV panels) suggests that they are pervasive in U.S. power system supply chains. For example, over 200 Chinese-manufactured high-voltage transformers were exported to the United States in the last decade. As noted above, such transformers are mostly manufactured abroad. Chinese components of potential concern are also in information and telecommunication technologies.

The Mumbai blackout in October 2020 is now suspected to be tied to a Chinese state actor, likely in retaliation to the border clash of summer 2020 and ongoing tension between India and China in the Himalayas. A Massachusetts-based company that tracks states' use of the internet believes that Chinese malware was flowing into the control systems that manage electric supply across India, along with a high-voltage transmission substation and a coal-fired power plant.[104] If correct, this may be the most prominent, known incident where a Chinese state actor successfully carried out a cyberattack against civilian critical infrastructure to advance some geopolitical objective.

U.S. Reponses

The United States has been enhancing its capacity to address cyber and other security risks to U.S. power infrastructure in recent years. Since the passage of the Energy Policy Act of 2005 (EPACT 2005), the Federal Energy Regulatory Commission (FERC) has been overseeing the reliability of the BPS. FERC certified the North American Electric Reliability Corporation (NERC) to be the nation's electric reliability organization that is responsible for developing Critical Infrastructure Protection (CIP) cybersecurity reliability standards. The BPS cybersecurity standards are mandatory and enforceable, although they are developed on a consensus basis before submission to FERC for approval. Also, cyber reliability for the BPS is covered by FERC jurisdiction, while that for DER is largely left to individual states and local distribution systems.

Cyberattacks on the U.S. electric utility sector have been on the rise. The electric utility sector faces millions of attempted cyber intrusions on a daily basis, seeing at least a seven-fold increase in frequency between 2011 and 2017.[105] Against this backdrop, the Trump administration issued Executive Order (E.O.) 13800, "Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure," in May 2017 to call for an assessment of a prolonged electric power outage resulting from a cyberattack. Per E.O. 13800, DOE established a five-year strategy for reducing cyber risks in the U.S. energy sector. DOE also established the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) in 2018 per the FAST Act.

The United States has also taken steps to address cyber threats that emanate from supply chain vulnerabilities. In July 2016, FERC issued Order No. 829, which directed NERC to develop a CIP reliability standard that would address software integrity and authenticity, vendor remote access, information system planning, and vendor risk management and procurement controls.[106] Accordingly, NERC developed a new CIP standard (CIP-013-1) to address supply chain risk management, which was approved by FERC in 2018 and entered into the implementation stage in October 2020 after a pandemic-induced delay.[107]

Moreover, the Trump administration issued E.O. 13920, "Securing the United States Bulk-Power System," in May 2020 to prohibit transactions that involve certain BPS electric equipment with a connection to a "foreign adversary" that may pose an undue risk of damage to the BPS, U.S. critical infrastructure, or the U.S. economy and national security. The order essentially sought to block U.S. federal agencies as well as persons from acquiring BPS equipment in which China has an interest. The order also authorized DOE to establish criteria for recognizing equipment and vendors as pre-qualified and identify now-prohibited equipment that is already in use. Per the order, then energy secretary Dan Brouillette issued the Prohibition Order Securing Critical Defense Facilities in December 2020, to bar utilities from purchasing sensitive grid equipment from China.

Investment Concerns

Additionally, investment in critical infrastructure, such as the electric power grid, has been a subject of government review. Investments—whether domestic or foreign—in an enterprise that owns or controls electricity facilities of a public utility are generally subject to FERC review. Specific to foreign investment, the Committee on Foreign Investment in the United States (CFIUS) is a major tool—and essentially the last resort—that the U.S. government has in screening foreign investments that may pose national security threats. CFIUS, established per the Defense Production Act of 1950, is an interagency committee which reviews transactions involving foreign investment in the United States that could result in control of U.S. entities and threaten to impair national security. Due to the confidentiality mandates of the CFIUS process, it is hard to ascertain how many cases involving Chinese investors have come before CFIUS review to date. However, many related to energy have presumably passed the review process, including the CFIUS approval in 2013 of the sale of battery technology developer A123 Systems to Chinese firm Wanxiang for $260 million.

To better safeguard U.S. energy facilities against national security threats that may emanate from foreign investment while still welcoming such investment, Congress passed the Foreign Investment Risk Review Modernization Act (FIRRMA) in 2018. FIRRMA strengthened and modernized CFIUS by broadening its scope to include certain real estate and other noncontrolling foreign investments on the basis of threats, vulnerabilities, and consequences to national security. The "noncontrolling foreign investment" focuses on U.S. businesses in technology, infrastructure, and data that perform "certain functions with respect to critical infrastructure," among others. Energy is within the "critical infrastructure" under CFIUS jurisdiction.[108] The new CFIUS regulations, which went into effect on February 12, 2020, are believed to be largely about addressing security threats that can arise from Chinese foreign direct investment (FDI) into the United States, including in the U.S. energy sector.

Additionally, transactions in equipment and components that may pose national security threats to the energy and power sector have become subject to a heightened level of scrutiny recently. In May 2019, the Trump administration issued E.O. 13873, "Securing the Information and Communications Technology and Services Supply Chain," which declared an "emergency" arising from the threat posed by "the unrestricted acquisition or use in the United States of information and communications technology or services designed, developed, manufactured, or supplied by persons owned by, controlled by, or subject to the jurisdiction or direction of foreign adversaries."[109] In response, the U.S. Department of Commerce issued an interim final rule on January 19, 2021, and created a new review process that can block a U.S. company from buying individual components from a foreign company subject to the jurisdiction of a "foreign adversary," such as China.[110] On March 22, the interim final rule came into effect. Transactions involving ICTS, which will be used in a sector designated as critical infrastructure by PPD- 21, including energy, appear to be subject to the ICTS review process.

Major Responses by U.S. Allies

China has been investing in the energy sector of the United States and its allied countries. Between 2005 and 2020, China's energy sector investment amounted to $16.75 billion in the United States, $76.65 billion in Europe, and $38.71 billion in Australia.[111] Security concerns over Chinese investment have also been on the rise among U.S. allies, however. In Europe, China State Grid has successfully invested in grid systems in countries such as Spain and Portugal, but their investment attempts have met pushback in France and Germany. In an effort to have some uniform view on what constitutes security threats from foreign investments, the European Union introduced new regulations on inbound FDI in October 2020, including for critical infrastructure, that are binding on all 27 member states. Also, in the United Kingdom, which recently left the European Union, the security implications of investment as well as potential nuclear reactor siting by China's state-owned nuclear enterprises have come under an intense scrutiny.[112] The National Security and Investment Bill, published in November 2020, would enhance the government's authority to screen investments that may pose national security threats by establishing a national security screening regime separate from competition regulation.[113]

Elsewhere, Japan has strengthened its Foreign Exchange and Foreign Trade Act (FEFTA), which regulates foreign investment in key sectors. For example, the 2019 amendment to FEFTA, which went into effect in May 2020, lowered the level of investment that requires pre-screening (from 10 percent to 1 percent) for foreign investors buying a stake in the "12 core designated business sectors."[114] The 12 sectors include electricity transmission and distribution, oil and gas pipelines, oil refineries, nuclear facilities, telecommunications, and cybersecurity-related services (e.g., network security monitoring and software).

Foreign investment review has been tightened also in Australia, where China State Grid became partial owner of Victoria's grid system as well as the natural gas distribution networks and transmission pipelines of Victoria, New South Wales, and the Australian Capital Territory (ACT). In spring 2020, in an effort to protect domestic assets vulnerable to bargain hunting due to the Covid-19-induced economic crisis, the Australian government initiated tightening of the country's foreign investment review process.[115] For example, following the passage of several relevant pieces of legislation in December 2020, prior approval by the Foreign Investment Review Board (FIRB) is required of a foreign person for a "notifiable national security action," which includes starting or acquiring a direct interest (10 percent or more) in a critical infrastructure business, such as electricity and natural gas.

Implications

Modern power generation and delivery systems depend on both operational and information technologies for which component supply chains are highly globalized. As such, further economic decoupling between the United States and China that entails a potential decision to phase out Chinese products could have cost implications or other complications for the U.S. electric sector. For example, in response to Trump's E.O. 13920 in May 2020, U.S. businesses, including equipment manufacturers and electric power generators and distributors, expressed overwhelming concern that the order to eliminate all or some equipment from specific suppliers would be too costly.[116] Also, there has been serious concern about the amount of time that would be required to replace such components. Electric suppliers spend years—not months—in designing, sourcing, manufacturing, and testing equipment before marketing products and systems. Some components are likely to be more difficult to replace for technical or quality reasons.

On April 20, 2021, DOE under the Biden administration formally revoked the December 2020 *Prohibition Order Securing Critical Defense Facilities*, while allowing E.O. 13920 to resume effect following a 90-day suspension.[117] Also on April 20, DOE introduced a 100-day plan—a coordinated effort between DOE, the electricity industry and the Cybersecurity and Infrastructure Security Agency—to enhance power sector cybersecurity and supply chains, and released a new Request for Information to seek input from a wide range of stakeholders to inform future executive actions.[118]

Power sector supply chain vulnerability is likely within the scope of the year-long review of the "energy sector industrial base" under the Biden E.O. 14017, "Executive Order on America's Supply Chains," issued on February 24, 2021.[119] If the U.S. government determines that actions are merited to remedy an existing vulnerability, government interventions must be more targeted and prioritized, and any steps to transition away from equipment made by China may have to be phased in over a longer period of time. If such interventions are to happen, they should be tied to more sustained support for investing in U.S. manufacturing capacity in key sectors or subsectors that would put the U.S. power system in a position to withstand—rather than react to—threats that are numerous, diverse, and evolving in nature as well as origin.

Another key consideration is whether and how decoupling would affect the pace of modernizing energy infrastructure in the United States. At one point, Chinese investment in U.S. energy infrastructure was on the rise. According to a 2013 report by the U.S. Chamber of Commerce, the energy sector was a key focus of China's infrastructure-related investment in the United States. Chinese investment in U.S. energy infrastructure—both existing and greenfield projects and assets—includes China Investment Corporation's purchase of a 15 percent stake in the power company AES in 2009 for $1.58 billion, and the 2013 joint venture between ENN Group of China and Utah-based CH4 Energy Corporation that entailed a nation-wide network of natural gas fueling stations in the United States. Between 2005 and 2020, 26 cases of Chinese investment in the U.S. energy sector took place, totaling $16.75 billion.[120] Investors included many major Chinese energy companies, such as CNOOC, Huaneng Power, Sinopec, and Sinochem.

A closer examination of recent Chinese investment in the United States reveals, however, that such investment seems to be on a steady decline since peaking at $53.12 billion in 2016.[121] Specific to the U.S. energy sector, there has not been Chinese investment since the second half of 2017.[122] While the cause of this decline is difficult to establish conclusively, likely factors at play include the Chinese government decision to tighten its capital outflows, U.S.-China trade tension, and CFIUS modernization. Given the current decline, further decoupling may not be a novel factor in terms of the United States' ability to afford modernization of its energy infrastructure.

4

Building a Strategic Response

Core Assumptions Guiding Policy

The existing market for low-carbon technologies will grow and expand over time to new fuels, products, and technologies. The question for the United States is who will supply these technologies. We recommend a strategy of reshoring, rerouting and rebalancing low-carbon energy supply in support of U.S. interests. This strategy is shaped by three core assumptions:

1. **The messiness of the energy transition cannot be an excuse to delay or to slow down the transition to a low-carbon future.** There is a narrative slowly emerging in some circles that it is better for the United States to double down on the hydrocarbons it produces rather than to import technologies of the future from China—essentially to pick self-sufficiency over climate action for national security or economic reasons.[123] But that view ignores the overarching need for the energy transition: this is not a path toward an abstraction such as “prosperity” or “improved living standards,” which is the typical arena where countries compete. Climate change is a real threat that must be addressed, and the world has a clear target: to reduce GHG emissions to net zero by 2050. The difficulty of achieving this goal is not a reason to give up—in fact, quite the opposite.

2. **The United States should take the strategic threats and vulnerabilities of a low-carbon world seriously.** Climate change is an existential threat, but that fact cannot be an excuse to downplay or ignore the risks of relying on China for key industrial goods; allowing Chinese components

into the U.S. electric system without significant oversight or defense buffers; looking away from child labor in the Democratic Republic of the Congo or forced labor in Xinjiang; or tolerating environmental degradation merely because the world "needs" the commodities that will power the energy transition. The imperative of climate change does not allow policymakers to neglect legitimate national security, economic, human rights, and environmental concerns.

3. **Decoupling from China in low-carbon energy is impossible today; in the future, it is improbable and likely expensive.** The United States can seek to reshore supply chains and manufacturing to try to make at home the nuts and bolts and the finished products of the energy transition—that is a legitimate political proposition. But it comes at a cost and will be shaped by reality. It took almost 50 years for the United States to achieve something close to the energy self-sufficiency that Richard Nixon first aimed for in 1973. And yet, despite having unrivaled industrial clout in hydrocarbons and immense natural resources, the United States continues to rely on other countries to meet demand in various U.S. regions. It is folly to think that decoupling from China in clean energy will be fast or painless if decoupling proves to be an enduring priority. It also may not be a desirable goal in and of itself. China is an important part of the clean energy economy and needs to continue on that path to achieve a shared global interest. The United States should also be wary of overreliance on any one country for a critical technology, rather than simply fixating on China.

The United States thus needs a twenty-first-century strategy for the geopolitics and geoeconomics of the energy transition. There is no one strategy that can meet the diversity of U.S. needs: not "innovation," "reshoring," or "being tough on China." In the years since the 1973 oil embargo, the United States has used a diverse system of strategies and institutions to manage energy insecurity and to steer the system to a new equilibrium. A similar strategic response is needed today, and that strategic response can be summarized as reshore, reroute, and rebalance.

Reshore

The rationale for reshoring is clear: sourcing commodities and making products in the United States reduces some of the vulnerabilities that come from import dependence while bringing the economic gains of emerging industries to the American people. Reshoring should not be a narrow concept—it is not merely about the relocation of supply chains or the effort to ensure that the next manufacturing plant is located in the United States rather than China. In a broad sense, reshoring is about identifying the supply chains and technologies where the United States has a competitive advantage or is most vulnerable and nurturing these technologies over time. It is both a response to decades of deindustrialization and an investment in the industries that will define the twenty-first century. A strategy to replace imported oil with domestically produced gas was a reshoring strategy, as was the push to blend biofuels produced at home into the gasoline supply. Reshoring has always been a complex and multifaceted undertaking, and promoting domestic manufacturing of clean energy will be no different.

The two preconditions for a successful reshoring strategy are (1) a large, stable market to demand fuels and products and (2) a dynamic and innovative industrial sector to supply them. For oil, this was never an issue: unfortunately, the United States never did curtail its demand for oil in absolute terms, even if the share of oil in the energy mix peaked in 1978.[124] For gas, the choice to restrict its use in electricity in the 1970s placed a limit on gas development (as did other regulations that distorted markets). In nuclear energy, the regulatory burden and cost overruns that bedeviled the industry after the Three Mile Island accident in 1979 offset the enormous research and development push that went into nuclear after 1974—a prescient example of the limits of an innovation-driven industrial policy without a corresponding market pull component.[125] Even in the case of unconventional gas and oil, it was the high prices of the 2000s (gas) and 2010s (oil) that enabled this sector to boom. Unless the United States becomes a big market for low-carbon energy, it is unlikely to become a major supplier or manufacturer of those related fuels and products.

The starting point for reshoring clean energy supply chains is to create demand for those technologies. The instruments for creating markets are well known, even if the specifics can be tinkered with over time or adjusted to the peculiarities of individual markets. Such instruments include:

- Strict rules that limit the market for polluting technologies (e.g., fuel economy standards for vehicles or emissions standards for industrial users and power generation);
- Targets and mandates that require market participants to source a portion of their needs from sources that meet certain criteria (e.g., renewable portfolio or renewable fuel standards);
- Taxes on activities that generate externalities (e.g., taxes on petroleum products, natural gas, or electricity). In the broadest sense, these could include carbon taxes or related levies that change the cost-benefit calculation for consumers (e.g., congestion charges for vehicles entering a city center);
- Financial incentives such as investment or production tax credits for companies to install new capacity or build new installations (e.g., chargers for EVs);
- Consumer-facing incentives to help users select a lower-carbon alternative (e.g., rebates for an EV, heat pump, or solar panel on one's house);
- Nudges for consumers to select a cleaner alternative, but without forcing that alternative (e.g., opt-out defaults for clean energy or energy efficiency labeling for consumer durables such as refrigerators, dishwashers, and cars);
- Government procurement practices to grow new technologies or expand markets (e.g., proposals to electrify the post office fleet, or to only source low-carbon steel or cement for new construction);
- Rules that ease the installation of low-carbon equipment such as solar panels or favor the use of low-carbon technologies (e.g., exemptions from driving restrictions for EVs, or automated permitting and pre-defined timelines for interconnection studies); and
- Focused investments in public infrastructure that make adoption easier (e.g., investment in highways was instrumental in expanding the market for cars).

On the supply side, reshoring is similarly grounded in policies the United States has used at various points in its history. At its heart, supply-side policies begin with innovation and the continuous investment made by federal and state governments, public institutions such as universities, and private companies to push the frontier of knowledge and commercialize new technologies. Without innovation, there can be no hope for leading in the markets that will be created in the future. A comprehensive innovation policy goes well beyond basic research and development but supports all stages of the innovation pipeline, from the emergence of a new idea, to its diffusion in commercial markets, to the reconfiguration of a technological system.[126] Such an innovation policy should include:

- Greater funding of federal and state government research, development, demonstration, and deployment (RDD&D), including co-investment funds between public and private partners;
- Articulate visions or missions for RDD&D activity in collaborative institutions and research agencies;
- Usage of federal and state public procurement powers to create early niche applications for new technologies;
- Capital grants, loans, and performance standards for firms in the early stages of technological commercialization; and
- Supportive public infrastructure around emerging, promising technologies.

But innovation is not enough and must be paired with a broader set of policies that encourage upstream supplies and domestic manufacturing. This is likely to be more difficult, with decades of attempts to reindustrialize the U.S. running up against the reality of globalized supply chains and economies of scale in low-cost manufacturing. A shortcut in thinking about where U.S. policy efforts should focus is that the goal should not be to substitute imports but to revive manufacturing exports. In other words, the United States should focus on industries where it can operate at the cutting edge and not throw good money after bad in an exercise of futile protectionism.

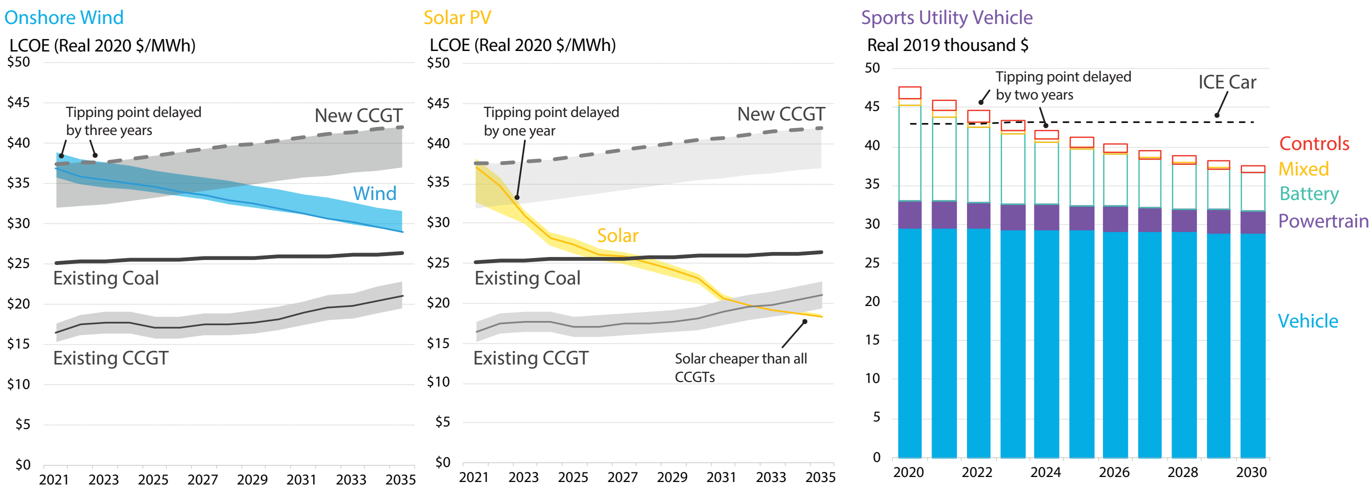
In pursuit of energy independence, for example, the United States took several measures to boost domestic oil supply. In November 1973, Nixon signed the Trans-Alaska Pipeline Authorization Act, which enabled the completion of a pipeline to ship oil from Prudhoe Bay to Valdez in Alaska. In 1975, the country instituted a ban on crude oil exports, creating a barrier between domestic production and international markets that lasted until 2015. While the federal government had leased areas in the Gulf of Mexico for hydrocarbon exploration before 1973, it was in the 1970s and 1980s that lease sales expanded and attracted greater interest.

Such a strategy could be adapted for the low-carbon era. As discussed earlier, the United States has engaged in a series of trade disputes with China that failed to save the solar manufacturing industry in the United States. (Wind has done much better.) A more purposeful and long-term strategy could have had better results than the strategy employed during the 2010s, when tariffs came at various bursts but were disconnected from any broader strategy to either deepen support for the market or bolster domestic manufacturers.

A plan to reshore manufacturing needs not be overly costly. In an analysis conducted for this report, BloombergNEF estimated how different levels of trade friction—for example, tariffs in response to subsidies or a form of local content requirement—could affect the cost of solar PV, wind, and lithium-ion batteries in the Unites States. The scenarios were designed to stimulate the comparison between a free-market world without barriers and one where there are some or many obstacles resulting from heightened competition or domestic industrial strategies with more assertive policy measures meant to create domestic economic benefits. The results were sobering—but encouraging for advocates for developing clean energy manufacturing in the United States.

In solar PV, BloombergNEF's "open markets" case assumed a 40 percent reduction in costs relative to the present, evidence of how much costs are already inflated by trade friction. The "mixed scenario" was based on current module pricing, while the "controls" scenario was an estimate of what a successful U.S.-based manufacturing industry might look like. The methodology was similar for lithium-ion batteries, with the "mixed" and "controls" cases stimulating different levels of U.S.-based manufacturing (the difference between the "mixed" and "upper bound" cases being a higher wage rate). The analysis on wind looked at previous examples of trade barriers of roughly 15 or 25 percent on several key components. The point of this exercise was to understand whether imposing certain costs to reshore industry would seriously slow the pace of decarbonization in the United States. The short answer is "not really." In each case, a critical tipping point, where the low-carbon technology becomes more competitive than an established technology, is delayed by a few years, which is a cost for sure, but not an insurmountable one.[127]

Higher Costs from Trade Friction Do Not Materially Slow the Deployment of Clean EnergyTechnologies



Source: BloombergNEF. Notes: CCGT is combined cycle gas turbine, ICE is internal combustion engine, LCOE is the levelized cost of electricity, MWh is megawatt hour. The mixed scenario for wind and batteries for electric vehicles assumes a 7 percent increase in costs relative to the baseline in the model. For solar photovoltaics (PV), the mixed scenario is a business as usual scenario since there are already costs from trade friction embedded in the model. The control scenario is shown in the shaded area and assumes a 10 percent increase in solar PV and a 20 percent increase in wind and batteries. The objective is to model how these higher costs might affect tipping points: the time at which solar, wind or electric vehicles become cheaper than their fossil-fuel based alternatives. For more details, see methodology section in BloombergNEF, "Clean Energy Trade And Manufacturing," May 2021.

In designing such a strategy, it helps to build on the competitive advantages that the United States already has, while developing those that will underpin future industries. The clean energy transition is likely to change the patterns of industrial production and comparative advantage over time, and existing advantages may count for little in a decade's time. Choosing which sectors to ignore will be as important as choosing which sectors to support. China, for example, has a competitive advantage in solar manufacturing because of low labor costs and its ability to generate increasing returns to scale in the manufacturing supply chain.[128] One study that examines countries' comparative advantages through relative export shares and green innovation capacity suggests that the United States has a competitive advantage in a green auto industry, for example, but risks losing market share to competitors in low-carbon chemical processing.[129]

The space is still wide open for the Unites States to dominate many of the industries critical to a clean energy transition. Carbon capture and storage, for example, is a business that fits with the industrial profile of the U.S. oil and gas sectors, as does hydrogen, where the United States lags far behind its peers. Offshore wind is another promising business where the United States can combine superior resources, superb industrial expertise in wind, and excellent legacy industrial capabilities in oil and gas that could be repurposed. Geothermal is yet another industry where the vast oil and gas services industry can leverage its expertise. Advanced nuclear power, biofuels, and battery storage using new chemistries all offer excellent opportunities for leadership and an active innovation space. They are also not areas where any competitor has established a lead yet. **Competing in low-carbon energy technologies is not about catching up or replicating what China has already done—it is about looking to the future and making big bets there.**

Of course, a self-sufficient system is still vulnerable to accidents or disruptions. Linkages to the rest of the world can add resilience and boost security; they can also lower costs and are, sometimes, impossible to avoid, especially for commodities that are internationally traded. Reshoring also takes time. The United States became a net energy exporter in 2019 for the first time in 57 years—46 years after Nixon first articulated such a target.[130] Reshoring was made possible by a mix of geology and market forces—a spike in oil and gas prices in the 2000s and early 2010s enabled the industry to produce enough oil and gas to make the country self-sufficient. And that was the product of a web of industrial organization, including entrepreneurs, financiers, service companies, and regulatory and land ownership structures. In short, it was the product of a long-term effort that depended on an industrial ecosystem for success. Self-sufficiency delivered some benefits but without totally freeing the United States from the threats that it originally tried to insulate itself from.

There are limits to reshoring, of course: not every material, component, and finished product will be sourced or manufactured in the United States. Countries trade to exploit natural resources and competitive strengths and to benefit from specialization and economies of scale. The clean energy supply chain is not different. The next two elements of the strategic response—reroute and rebalance—are focused on managing that trade.

Reroute

A reliance on imports does not automatically entail danger or vulnerability, but different configurations represent different threat levels. One option for the United States is to **nurture ties with suppliers that carry limited or no geopolitical baggage.** European companies have always enjoyed a close relationship with Norway, partly as a way to hedge against undue exposure to Russian gas. For years the United States mostly imported gas from Canada, and this import dependence never rose to the level of strategic criticality that oil did. China sees a similar possibility in sourcing gas from Central Asia, bypassing the shipping lanes controlled by the U.S. Navy and relying on countries with whom it enjoys a vast imbalance in power. Relying on Australia for lithium is not the same as relying on the Democratic Republic of Congo for cobalt.

Another option is to **encourage supply diversification,** harking back to Winston Churchill's mantra that "safety and certainty in oil lie in variety and variety alone."[131] The United States, for instance, relies on uranium from four primary suppliers, but none of them has a market share much above 20 percent, and two of them are close U.S. allies (Canada and Australia).[132] Both Japan and the European Union have pursued regional diversification strategies in order to diversify from suppliers that they deemed worrisome (chiefly the Middle East and Russia).

As Japan turned to gas after the 1973 oil embargo, the country helped expand the LNG industry, offering prospective exporters a packaged deal that included financing, long-term contracts to buy gas, and engineering capabilities to manage construction. Over time, the Japan Bank of International Cooperation has financed LNG projects in Qatar, Australia, Russia, Malaysia, Brunei, Papua New Guinea, Equatorial Guinea, and the United States, a remarkable example of a country-driven regional diversification strategy.[133]

Europe pursued a similar strategy, although less coherently. Individual countries and companies engaged with gas suppliers such as Norway, Algeria, or Libya to secure gas beyond the Soviet Union or Russia. In the Caspian, there was a concerted effort to bring natural gas from Azerbaijan into Southeast Europe—this long-sought-after "Southern Corridor" finally materialized in 2020. And, to a lesser extent, Europe has engaged with countries such as Turkmenistan, suppliers in the Eastern Mediterranean, and even West Africa to secure additional gas (the last via the Trans-Saharan Gas Pipeline Project).

The United States can also follow the Japanese or European examples in gas by going overseas and building new supply chains where the conditions are favorable. The United States does not need to produce every critical mineral within the boundaries of the country; it can leverage institutions such as the Export-Import Bank (EXIM) of the United States or the International Development Finance Corporation (DFC) to encourage the development of new mines for lithium or cobalt or to open up new factories that supply the components for solar panels, wind turbines, or batteries. For example, among U.S. allies, Mexico, Canada, and Australia all have significant critical mineral resources. EXIM has played a critical role in developing the world's LNG market; why not do the same for new technologies?

Rebalance

When relying on imports is unavoidable, and where those imports come from suppliers that raise a number of strategic, economic, human rights, or environmental concerns, the United States and other counties have long relied on an extensive tool kit to manage risks. These tools can be grouped under the theme of "rebalance" because they are fundamentally about creating a foundation for these trade relationships that protects U.S. interests. Such a strategy can rest on six elements: (1) clearly delineating threats; (2) creating interdependence; (3) creating or adapting international institutions to manage insecurity; (4) leveraging domestic policy and institutions to shape the behavior of external suppliers; (5) creating strategic buffers; and (6) relying on deterrence to prevent overt attacks.

The first element is a need to clearly delineate what is a threat and what is not. To say that "x percent of U.S. solar modules come from China" is a starting point for the conversation, not a definitive statement that conveys a specific threat. Countries have developed complex calculations to identify bottlenecks and possible threats, and to estimate the resilience of their systems to those threats. Such exercises are long-established in hydrocarbons and in electricity; they are generally absent from low-carbon energy technologies in part because these technologies are just now being scaled and in part because a trade in intermediate manufactured products is harder to map than the trade in fuels.

Such analytical work must recognize that the threat landscape will change as the world transitions from hydrocarbons to low-carbon energy resources. Oil, gas, and coal are not the same as wind, solar, batteries, biofuels, or hydrogen. A digitalized grid is not the same as the refineries and pipelines of the hydrocarbon era. Trade in commodities with volatile prices is not the same as trade in solar panels or wind turbines. When fuel supplies are interrupted, people's way of life can be instantly disrupted; a cessation in the trade for manufactured products might only impact investment in new capital and thus have a different economic effect. And, of course, the geography of supply will hinge not on only geology but also on industrial might more broadly—which means there is opportunity to shape supply chains in a way that was often impossible to do with fossil fuels.

Even so, some risk is unavoidable. There is no such thing as perfect security. But there is a difference between uncertainty which is hard to pinpoint and risks that are easier to gauge. There are so many ways to understand risk: mapping the supply chains and understanding concentration and bottlenecks; quantifying the utilization of the system and its spare capacity; understanding the legal, regulatory, or contractual rigidities in the system; and studying the behavior of the main players to gauge how they might react in a crisis (or what might prompt them to initiate an attack). These are all tools that the United States can adapt to the low-carbon era.

A second element is to create interdependence. The goal is to find the space to maintain trade relations either due to a quid pro quo or an understanding that to damage these relations would be politically costly. The relationship between the United States and Saudi Arabia could be seen in this light, even if the "oil-for-security" characterization tends to oversimplify the complexity of the bilateral relationship. The approach taken by West Germany toward the Soviet Union, and later by Germany toward Russia, is in a similar political and philosophical vein: the trade in gas persists because to interrupt it would be seen as a massive escalation by the other side.

Such links are often anchored in corporate relations: Saudi Aramco has long been an investor in refining in the United States, as has PDVSA, the Venezuelan state-owned oil company. There are German companies that invest in Russian energy and Russian energy companies that invest in Germany. These relationships sometimes convey a level of discomfort because they are seen as inherently fragile or a compromise. But creating deep ties as a way of preserving a relationship or raising the costs of disruption is a well-established method that countries have pursued in dealing with each other. To merely sever ties is sometimes more costly. It pays to have a thoughtful way to gauge which kind of links might make sense as a way to insulate a relationship from unraveling.

In the context of the U.S.-China relationship, businesses are often seen as a ballast that might prevent an escalation in tensions. In such a complicated and high-stakes relationship, economic ties are unlikely to overrule core national security concerns. But they can still preserve some opportunities to talk; they nurture personal connections that can matter either in a crisis or an effort to thaw a relationship. Trade in strategic commodities also creates a mutual vulnerability. China has always feared the U.S. Navy and its control of sea lanes, but in recent years, China has also become more reliant on U.S. hydrocarbon exports. Such trade flows create an interdependence that is costly to disrupt and important for each party to defend.

The United States could reach an implicit or explicit quid pro quo with China. For example, the United States could tie the export of critical technologies and products that the United States exports to China to critical technologies that the United States wants from China. Or the United States could more explicitly ringfence certain products from trade disputes, ensuring that critical minerals, rare-earth metals, and key technologies are insulated from broader trade tensions. These, again, are strategies that countries have employed in the past to manage trade with adversaries.

The third element is to set up or repurpose international institutions to manage insecurity. The International Energy Agency is the most visibly important for global energy security. But other initiatives exist to support specific goals: the Extractive Industries Transparency Initiative is designed to improve financial transparency between companies and governments; the Energy Charter Treaty aims to streamline cross-border investment rules for the sector; and the International Atomic Energy Agency was built to mitigate the proliferation challenges that come from an expanded use of civilian nuclear power. And these initiatives are supplemented by regional or bilateral forums and dialogues that are all meant to bridge the gap between countries pursuing different goals.

The United States can also assume a leadership position in developing institutions that increase price transparency and accountability for products for which use will only grow with time. Where there are concerns over forced or child labor, the United States could use its power as a major market, ideally alongside like-minded allies, to establish standards for products that end up in installations or equipment in the United States, Europe, or elsewhere. These efforts could help mitigate some of the egregious examples of human rights violations but also set a foundation for ensuring that the United States manages the side-effects of a significant scale up in mining and manufacturing capacity for clean energy.

Establishing rules of the road can also be important given an expected increase in government interference. Unless there is some understanding about what is in bounds and what is not, the trade conflicts experienced over the past decade will merely multiply. This strategy does not require the United States to press for free markets—in oil and gas, the country has made its peace with the existence and prevalence of state-owned firms in much of the developed world. A similar accommodation could be imagined for clean energy technologies.[134]

The fourth element is domestic institutions that can shape the behavior of suppliers. The United States has often used the threat of anti-trust measures to occasionally pressure OPEC. Europe has been even more successful in that regard, leveraging the principles behind the Single European Market to force fundamental changes in how markets are structured: eliminating long-term contracts, forcing the gradual separation between the supply of energy and its transportation, encouraging stronger regulatory oversight and cooperation between member states, investigating and forcing large energy companies to comply with the rules, and using such tactics even against foreign suppliers such as Algeria's Sonatrach or Russia's Gazprom.

Different problems will require different solutions. The United States has used trade policy to punish foreign companies that receive undue support from their governments (even if such policies failed to protect U.S. industry). Developing verifiable rules of origin could be useful in minimizing the use of child or forced labor or in limiting extraction that uses environmentally unsound practices. Product standards are another way to level the playing field—for instance, insisting on design choices that allow for recycling or specifying maximum content for various components. Such provisions could achieve public policy ends, but they could also prevent a race to the bottom that hurts U.S. or Western firms. And, of course, the United States has often used sanctions to shape the behavior of other countries.

A fifth element could be to build strategic buffers for the low-carbon era. In retrospect, it is always hard to gauge the significance of an institution such as the Strategic Petroleum Reserve; it has been used sparingly, and it is impossible to construct a hypothetical experiment where it did not exist to assess what difference it made. Yet the United States still has experience that could be relevant: what goods to stockpile, what kind of buffer is sufficient, who should pay for those stockpiles, how those costs might be shared with other countries, under what conditions might the stocks be drawn down, and so on. In each of these questions, the experience of oil and gas can be instructive.

The final element is deterrence. The United States has spent decades thinking about sea lanes and chokepoints and has pursued a policy to prevent any single power from dominating the Persian Gulf. In a low-carbon world, theaters and priorities will shift. But deterrence can still be important, especially in terms of cybersecurity. The United States can adjust supply chains to reduce its reliance on Chinese products and components, and it can improve the oversight of those components and boost the resilience of the system to a disruption. But in the final analysis, the best defense against an attack will be fear of retaliation. What is most needed, therefore, is a clear conception of the rules of engagement—of what type of actions the United States will find intolerable as its own definition of energy security shifts over time.

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About the Authors

Nikos Tsafos is interim director and senior fellow with the Energy Security and Climate Change Program at the Center for Strategic and International Studies (CSIS). In this role, he leads the program's work on managing the geopolitics of energy and climate change, advancing industrial policies for clean energy, ensuring a just transition for workers and communities, and equipping U.S. foreign policy and the multilateral system to deal with climate change and the energy transition. Nikos has written extensively on the geopolitics of energy and natural gas, the political economy of hydrocarbon states, European climate policy, sustainable cities and mobility, the pace and trajectory of the energy transition, and the geopolitics of energy in the Arctic, Europe, the Eastern Mediterranean, and Southeast Asia.

Lachlan Carey is an associate fellow with the CSIS Energy Security and Climate Change Program. His research interests include the geopolitics of energy, climate change policy, and international trade. Mr. Carey was previously a consultant with the World Economic Forum and before that worked in the Australian Treasury Department in Canberra. He holds a master's in public affairs from the Woodrow Wilson School at Princeton University and a Bachelor of Commerce (liberal studies) from Sydney University.

Jane Nakano is a senior fellow with the CSIS Energy Security and Climate Change. Her research interests include U.S. energy policy; global market and policy developments concerning natural gas, nuclear energy, and critical minerals; and energy security and climate issues in the Asia-Pacific region. She frequently writes and speaks on these issues at domestic and international conferences and to media around the world. She has also testified before Congress on U.S. liquefied natural gas (LNG) exports and before the U.S.-China Economic and Security Review Commission on U.S.-China nuclear energy cooperation. Prior to joining CSIS in 2010, Nakano worked in the Office of Policy and International Affairs in the U.S. Department of Energy, where she covered a host of energy, economic, and political issues in Asia. From 2001 to 2002, she served at the U.S. embassy in Tokyo as special assistant to the energy attaché. Nakano graduated from Georgetown University's School of Foreign Service and holds a master's degree from Columbia University's School of International and Public Affairs.

Sarah Ladislaw is a managing director at Rocky Mountain Institute (RMI), an independent, non-partisan, nonprofit organization of experts across disciplines working to accelerate the clean energy transition and improve lives. RMI's mission is to transform the global energy system to secure a clean, prosperous, zero-carbon future for all. Ladislaw leads the U.S. program at RMI and works on other global initiatives to reduce industrial sector emissions and support the development of green banks. She was previously senior vice president and director of the Energy Security and Climate Change Program at the Center for Strategic and International Studies (CSIS), where she led the think tank's work in energy policy, geopolitics, and technology analysis. Ladislaw spearheaded new work at CSIS on climate change and foreign policy, deep decarbonization, and just transitions. She authored numerous publications on the geopolitics of energy, energy security and climate change, and the energy transition.

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