Working Paper for the Penn Project on the Future of U.S.-China Relations [updated Spring 2021]

Why We Can't Fix the Climate Crisis Without China

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The United States and China jointly account for 40 percent of global greenhouse gas emissions, putting these two nations at the center of any successful attempt to curb emissions to the levels required to prevent catastrophic climate change. Climate change is a global problem of unparalleled dimensions that requires a global response, including in the invention, commercialization, and production of technologies that can forge deep decarbonization. China currently has unique skills in the production of clean energy technologies that are rooted in the nation's unique economic institutions and are therefore difficult to replicate elsewhere. Collaboration has been central to the development of global clean energy industries, including collaboration between Chinese and American firms. While such collaboration inevitably entails risks, they can be mitigated. Recent institutional reforms in China have begun to do so, but more needs to be done to level the playing field in China and maintain open borders in the United States. Instead of seeking to decouple from the Chinese economy, the United States should ramp up its domestic investments in both R&D and domestic manufacturing capabilities in clean energy sectors, all while working with China to accelerate the deployment of low-carbon energy technologies. The urgency of emissions reductions leaves few alternatives to the current division of labor in global clean energy supply chains, and governments should work to foster such collaboration. While this division of labor is neither fixed nor inevitable, only long-term investments in domestic clean energy industries will allow the U.S. to change the terms of its relationship with China in clean energy industries without jeopardizing global climate goals.

Economic decoupling and climate change

Long before the onset of the Covid-19 pandemic, voices across the political spectrum in Washington began advocating for economic decoupling from China. Although opinions differed on what exactly such measures should entail, bipartisan consensus emerged that China was unwilling to accept global rules of engagement, requiring the United States to shift strategy. At its core, such views originated in the realization that the core assumptions underlying U.S.-China relations in recent decades had been unsound: economic integration has not in fact led China to align with Western political norms and economic practices. China has been increasingly unwilling to "play our game."[1] On the left, the Center for American Progress called for steps to "limit, leverage, and compete" with China, essentially advocating a strategy of putting U.S. interests first and using economic interdependence as political gain.[2] On the right, the Trump administration discovered tariffs as its preferred instrument for leveraging economic interdependence in a renegotiation of the U.S.-China economic relationship. The Covid-19 pandemic further accelerated such tendencies, highlighting not only the vulnerability of the world's economic supply chains to external shocks, but also strengthening mercantilist calls for national self-sufficiency in China, the United States, and elsewhere The Biden administration, while retreating from the isolationist stands of the Trump administration, has thus far refrained from rolling back existing tariffs. Domestic policy initiatives, most notably the "American Jobs Plan," are explicitly framed as responses to competition with China, suggesting that the relationship will remain complex for the foreseeable future.[3]

Few industries have more at stake in these battles than those producing low-carbon energy technologies (LCET), including wind turbines, solar panels, electric vehicles, and lithium-ion batteries that are increasingly needed for electric cars and on-grid storage. Since joining the WTO in 2001, China has increased its share of global solar PV production from less than 1 percent to over 60 percent of the world's solar panels. China now makes more than one third of global wind turbines, is the world's largest producer of (and market for) electric cars, and

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[1] Edward S. Steinfeld, *Playing Our Game: Why China's Rise Doesn't Threaten the West*, (New York, NY: Oxford University Press, 2010).

[2] Melanie Hart and Kelly Magsamen, "Limit, Leverage, and Compete: A New Strategy on China," Center for American Progress, 2019, Accessed May 5, 2020, https://www.americanprogress.org/issues/security/reports/2019/04/03/468136/limit-leverage-compete-new-strategy-china/.

[3] Henry Farrell and Abraham Newman, "Will the Coronavirus End Globalization as We Know It?" *Foreign Affairs,* (May/June 2020).

commands more than two thirds of global production capacity for lithium ion batteries.[4] In large part because of China's unprecedented investment in manufacturing capacity in these sectors, cost of LCETs has fallen sharply. Since 2009, prices for wind turbines and solar panels have decreased by 69 percent and 88 percent, respectively, making these technologies competitive with conventional sources of energy in many parts of the world. This is particularly the case when they are deployed in conjunction with battery storage, where China's massive investments in new manufacturing capacity have also led to rapid cost declines.[5]

The unique geography of LCET supply chains—some of the first industries to emerge after globalization led to a wholesale reorganization of the global economy in the 1990s—make U.S. collaboration with China fundamental in any effort to avoid the worst consequences of climate change and, indeed, be beneficial to the United States. Meeting the goals of the Paris Agreement will require net-zero emissions by 2050 and substantial reductions before then. Already by 2030, emissions must have peaked and begun declining among major industrialized economies given the limited remaining carbon budget (IPCC 2018). In this timeframe, it is unrealistic to expect that any other economy will be able to replicate or surpass China's infrastructure for the production of LCET technologies required to meet these goals.

Against this background, I offer three facts and one recommendation on U.S.-China relations and the global climate crisis. First, I show that China has unique skills in the production of clean energy technologies that are rooted in the nation's unique economic institutions and are therefore difficult to replicate elsewhere. Second, I chronicle how collaboration has been central to the development of global LCET industries, including collaboration between Chinese and

[4] John Helveston and Jonas Nahm, "China's key role in scaling low-carbon energy technologies," *Science* 366, no. 6467 (2019): 794. doi: 10.1126/science.aaz1014.
[5] "Lazard's Levelized Cost of Energy Analysis," Lazard, 2018, https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf.

American firms. Third, while such collaboration inevitably entails risks, they can be mitigated. Recent institutional reforms in China have begun to do so, but more needs to be done to level the playing field in China and maintain open borders in the United States. I end by suggesting a different approach, which I call "conscious collaboration:" the United States should ramp up its domestic investments in both R&D and domestic manufacturing capabilities in LCETs, all while working with China to accelerate the deployment of low-carbon energy technologies. The urgency of emissions reductions leaves few alternatives to the current division of labor in global LCET supply chains, and governments should work to foster such collaboration. While this division of labor is neither fixed nor inevitable, only long-term investments in domestic LCET industries will allow the U.S. to change the terms of its relationship with China in clean energy industries without jeopardizing global climate goals.

<u>Fact 1: China has unique skills in manufacturing innovation in clean energy industries</u>

Particularly in LCET sectors, skills in the commercialization and mass production of new technologies are now concentrated in China. In the late 1990s and early 2000s, when the first Chinese firms entered wind and solar PV sectors, few global manufacturers of wind turbines and solar panels were producing at scale. While technology could be accessed in global networks through licensing and joint venture agreements, mass production knowledge was rare in these emerging industries. Chinese firms subsequently focused their efforts on building research and development skills around the commercialization and rapid scale-up of complex wind and solar technologies. Designated engineering teams with advanced capabilities in rapidly translating complex technologies into mass-manufacturable products. Such tasks required improvements to process designs long associated with manufacturing innovation, but also entailed changes to product designs to accommodate manufacturing requirements, to incorporate new materials and components, and to meet cost targets for final products.[6] The majority of these producers continued to license technology and source components and production equipment abroad.[7]

The development of these capabilities in manufacturing innovation relied on two unique institutional features of China's domestic economy that supported investments in both innovation and manufacturing: central government incentives for R&D and local government support for manufacturing. To date, no other economy has been willing and able to devote a similar level of resources in the expansion of manufacturing capacity and manufacturing R&D in LCET sectors. Since the beginning of the reform period in the 1980s, the central government in Beijing has used state incentives to encourage the development of domestic R&D, including applied research in manufacturing. Such government R&D support expanded in 2006, when the central government began encouraging "indigenous innovation" to reduce dependence on foreign technologies through increased domestic R&D efforts. Efforts further accelerated under President Xi's Made in China 2025 initiative, which has also designated the development of domestic LCET sectors as a strategic national priority. Provincial and municipal governments, dependent on tax revenue from the local manufacturing economy, augmented central government R&D support with incentives for mass production. China's provincial and municipal governments repurposed central government resources to broker bank loans and provide land, facilities, and tax incentives to manufacturers, including in LCET sectors that were unable to attract large-scale financing in other parts of the world. Such loans for manufacturing facilities were provided even as central government policies encouraged industry consolidation. It is

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[6] Jonas Nahm and Edward S. Steinfeld, "Scale-up Nation: China's Specialization in Innovative Manufacturing," *World Development* 54, (2014): 288-300, http://dx.doi.org/10.1016/j.worlddev.2013.09.003.
[7] Joanna I. Lewis, *Green Innovation in China: China's Wind Power Industry and the Global Transition to a Low Carbon Economy*, (New York, NY: Columbia University Press, 2013).

estimated that between 2010 and 2012 alone, wind and solar firms received credit lines of USD 47 billion by Chinese banks. The China Development Bank, one of three state-owned policy banks, reportedly extended USD 29 billion in credit to the 15 largest wind and solar firms.[8] Other reports suggest that state-owned banks provided USD 18 billion in loans to large wind and solar firms for the expansion of manufacturing facilities. These loans were backed by municipal and provincial governments, allowing firms to expand manufacturing capacity even after the global financial crisis in 2009, when the collapse of European markets led to global overcapacity and few lenders were willing to fund further expansion of manufacturing plants.[9]

While national policies designated strategic technologies and provided funding for R&D, local policies diverted those resources into mass manufacturing clusters. In this environment, Chinese manufacturers continued to center their R&D efforts on production improvements rather than new product R&D.[10] To ensure that firms would rapidly contribute to the local economy, local administrations have frequently made subsidies conditional on meeting production targets and revenue requirements. In many instances, firms were contractually obliged to build facilities with pre-determined manufacturing capacity by a particular date or risk losing government grants, tax reductions, and discounts on land prices. In other cases, local governments informally exerted pressure on firms to rapidly scale production.[11] As Chinese manufacturers in LCET sectors focused on commercialization, scale-up, and cost reduction, their innovative manufacturing capabilities (rather than basic factor cost advantages) emerged as a key source of competitive

[8] Sally Bakewell, "Chinese Renewable Companies Slow to Tap $47 Billion Credit," *Bloomberg*, November 16, 2011, https://www.bloomberg.com/news/articles/2011-11-16/chinese-renewable-companies-slow-to-tap-47-billion-credit-line.
[9] Keith Bradsher, "Glut of Solar Panels Poses a New Threat to China," New York Times, 2012, Accessed May 1, 2020, http://www.nytimes.com/2012/10/05/business/global/glut-of-solar-panels-is-a-new-test-for-china.html?_r=0.
[10] Nahm and Steinfeld, "Scale-up Nation."
[11] Jonas Nahm, "Exploiting the implementation gap: policy divergence and industrial upgrading in China's wind and solar sectors," *The China Quarterly* 231 (2017): 705-727.

advantage.[12] Yet, even with China's highly supportive domestic institutions and rapid developmental pace, it took nearly four decades for Chinese firms to establish the capabilities in commercialization and scale-up that the world now needs to bring new energy technologies to market. *It is highly unlikely that any other economy will be able to replicate China's skills in scale-up and mass production in the timeframe required to avoid the worst consequences of climate change.*

Fact 2: Clean energy technologies have come to market as the result of collaboration

The United States government has historically been the largest investor in clean energy R&D.[13] Major technological advances, including the first solar photovoltaic cells, stem from U.S. laboratories. U.S. universities and government research institutes remain at the frontier in the development of a range of new energy technologies, including next-generation solar PV, distributed wind power, and advanced battery chemistries. In the United States, the vast majority of wind and solar firms were startups with skills in the *invention* of new technologies, but with far fewer capabilities focused on the commercialization and production of these inventions. In 2009, out of 100 solar PV firms operating in the United States, at least 73 were startups working on the development of next-generation solar technologies. Most of these startups lacked in-house production capabilities.[14] Of course, possessing intellectual property does not immediately lead to the successful commercialization of a product or technology. Firms need complementary assets, such as financing, manufacturing capabilities, and distribution channels, that they may not

[12] Edward S. Steinfeld and John Deutch, A Report For the MIT Future of Solar Energy Study, Cambridge MA, 2013.
[13] National Science Board, Science and Engineering Indicators 2018 (NSB-2018-1), (Alexandria, VA: National Science Foundation, 2018).
[14] Jonas Nahm, "Renewable futures and industrial legacies: Wind and solar sectors in China, Germany, and the United States," *Business and Politics* 19, no. 1 (2017): 68-106; Gregory F. Nemet, *How Solar Energy Became Cheap*, (New York, NY: Routledge, 2019).

internally possess or have access to in their home markets. However, since at least the 1980s, the U.S. innovation system has moved away from large, vertically-integrated firms that could manage the entire commercialization process in-house towards smaller, entrepreneurial firms focused on the invention of new technologies, with manufacturing increasingly outsourced and offshored.[15] An eroding "industrial commons" has left many U.S. startups with few options but to collaborate with foreign partners to access the capital and manufacturing capabilities needed to bring their technologies to market.[16]

Access to financial investment and the innovations of Chinese manufacturers in product scale-up and cost-reduction has increasingly led firms in a variety of industries to commercialize their technologies in China. Meanwhile in China, large wind and solar manufacturers focus on R&D required for commercialization and scale-up of novel technologies, which I refer to as *innovative*. Chinese firms were the first to bring wind and solar technologies to mass production as a result of such investments.[17] More than mere customers, Chinese manufacturers became long-term partners in the development of production equipment for new solar PV technologies. In the process of bringing new solar technologies from lab to market, China's producers were willing to take considerable risks in the development and application of new production technologies and materials. In the solar sector in particular, Chinese firms were the first to use new, fully automated production lines, for which the equipment primarily came from suppliers in Europe and the United States.

In LCET sectors, collaboration with Chinese firms—not competition from them—has enabled new technologies from around the world to be commercialized in larger quantities and at

[15] Richard K. Lester and David M. Hart, Unlocking Energy Innovation: How America Can Build a Low-Cost, Low-Carbon Energy System, (Cambridge, MA: MIT Press, 2011).
[16] Gary Pisano and Willy C Shih, "Restoring American Competitiveness," *Harvard Business Review,* (July 2009).
[17] Jonas Nahm, "Exploiting the implementation gap."

increasingly competitive prices. For instance, Innovalight, a U.S. startup, developed a nanomaterial with application in the solar industry with funding from the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL). Although Innovalight and its research partners in the United States were able to determine that the nanomaterial could increase cell efficiency by up to fifty percent, it was through collaboration with a Chinese partner, JA Solar, that Innovalight was able to commercialize its technology. Under a collaborative development agreement, engineers from JA Solar and Innovalight jointly adapted the technology for use in mass manufacturing and successfully incorporated the new material in existing production processes in JA Solar's manufacturing facilities in China. The production lines on which such tests occurred were developed in collaboration with German SMEs. JA Solar's focus on innovation related to scale-up and mass production ultimately enabled the commercialization of Innovalight's technology, which the startup was subsequently able to sell to a wide range of solar manufacturers in China.[18]

For U.S. wind energy firms with capabilities in the invention of new technologies, global partners supplied both componentry and design-for-manufacturing expertise. GE, which entered the wind industry during the late 1990s through the acquisition of several wind turbine startups, relied on capabilities in Chinese firms while retaining a focus on invention of control software and new turbine technologies. GE gearboxes, for instance, were developed in collaboration with the German firm Eickhoff. According to GE's chief wind engineer, Vincent Schelling, GE has to "put the knowledge in the gearbox manufacturers' hands. It would be better if we designed the gearbox and they built it, but we don't have all the knowledge."[19] Over time, as increasing global demand for wind turbines necessitated ever larger manufacturing runs, Chinese suppliers offered

[18] Nahm and Steinfeld, "Scale-up Nation."
[19] Eize de Vries, "Close up - own foundries give strategic edge," *Windpower Monthly* (March 2013); *Windpower Monthly*, "A more conservative approach," (November 2005).

engineering capabilities focused on changing product designs to accommodate lower-cost manufacturing processes. As early as 2006, GE began co-developing gearboxes with Nanjing-based NGC to take advantage of local expertise in mass production.[20] By 2008, more than half of NGC's products were exported and their gearboxes were used in a wide range of GE wind turbines in all of GE's global markets.[21] Similar patterns of collaboration are now emerging in the automotive sector, where manufacturers from around the world are working with Chinese manufacturers to develop lithium-ion batteries that meet their specifications.

Successful collaborations with Chinese manufacturers have led to multidirectional learning: Chinese manufacturers have gained technological know-how from advanced foreign firms, and the foreign partners have incorporated the manufacturing and scale-up solutions their Chinese partners identified into up-stream R&D activities.[22] *If any reshoring of manufacturing is going to occur in the U.S. economy, partnering with and learning from the innovations of Chinese manufacturers will be important. In the meantime, working with Chinese producers remains the most viable option for U.S. innovators to bring new energy technologies to market quickly and at prices that allow them to compete with existing energy infrastructure.*

Fact 3: On climate, the benefits of collaboration outweigh the risks

Entering into collaborations with Chinese firms has of course not been without risk. China has historically set an uneven playing field in its domestic market in favor of Chinese firms, and in some sectors, such as wind energy, foreign firms have been systematically pushed

[20] *Windpower Monthly*, "Gearbox supply in Asia and Europe expands – Wind power now an industry worth making investments for," (October 2006).
[21] *Windpower Monthly*, "China gearbox factory orders 5000 high capacity bearings," (September 2008).
[22] Jonas Nahm, "Renewable futures and industrial legacies"; Gary Herrigel, *Manufacturing possibilities: creative action and industrial recomposition in the United States, Germany, and Japan*, (Oxford: Oxford University Press, 2010).

out of China's market through discriminatory government procurement policies.[23] Even though local content requirements for wind turbines were removed in 2009 and no formal nationality requirements were part of China's feed-in tariffs, foreign wind turbine manufacturers complained about being systematically excluded from government tenders and undercut by local competitors.[24] Despite having established local manufacturing facilities in China, foreign manufacturers argued that central and subnational governments were making use of the government procurement clauses included in the indigenous innovation legislation to purchase from domestic firms.[25] Many foreign firms ceased to participate in public tenders and subsequently scaled down planned investments in China-based manufacturing facilities. In other industries, such as the auto sector, foreign firms have been forced to share IP and profits with Chinese partners in order to gain market access. Although forced partnerships have often failed to produce serious Chinese competitors, these policies do not create an inviting environment for collaboration. Allowing foreign firms fair access to its domestic market is one step China should take to encourage increased collaborations with foreign firms.

In some areas, the situation is improving. In 2018, the central government announced it would remove the joint venture requirement for electric vehicle manufacturers so that foreign firms could wholly own their enterprises in China, and this ruling will extend to all auto manufacturers in 2020. Tesla was one of the first foreign manufacturers to build its own manufacturing facility in China as a result of these changes, much to the chagrin of local competitors who complained about the subsidies it received from the Shanghai government.[26]

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[23] Joanna Lewis, *Green Innovation in China.*
[24] Keith Bradsher, "On Clean Energy, China Skirts Rules," *New York Times*, September 8, 2010, https://www.nytimes.com/2010/09/09/business/global/09trade.html.
[25] Xielin Liu and Peng Cheng, "Is China's Indigenous Innovation Strategy Compatible with Globalization?" In *Policy Studies,* Honululu: East-West Center, (2011): 25-26.
[26] Ryan McMorrow, "Tesla lines up $1.6bn in financing for its Shanghai Gigafactory," *Financial Times*, December 27, 2019, https://www.ft.com/content/598b04cc-286d-11ea-9a4f-963f0ec7e134.

China's IP institutions are also strengthening, even though IP theft remains a serious problem. In 2014, China established the first dedicated IP courts in Beijing, Shanghai, and Guangzhou, with additional courts added in 2017. Researchers estimate that the vast majority of the cases in the Beijing and Shanghai courts have ruled in favor of foreign plaintiffs against Chinese infringers. Damages paid to foreign plaintiffs were on average three times greater than those paid to domestic victims of IP theft. Nonetheless, domestic firms are increasingly making use of the courts to protect their IP. In 2015, 88.5 percent of the roughly 11,000 patent cases involved a Chinese plaintiff and Chinese defendant.[27]

Governments in both China and the United States should play a constructive role in mitigating concerns over IP and fostering global ties. Governments can level the playing field and reduce risks for firms to work with one another, and they are critical agents in building and supporting global networks of innovators. The U.S. and Chinese governments have done so in the past. The U.S.-China Clean Energy Research Center (CERC), spearheaded by former U.S. energy secretary Steven Chu in 2009, established a $150 million joint pledge by both governments to increase innovation in clean energy technologies. At its core, CERC established a Technology Management Plan to help govern and mitigate IP concerns. Although little of the IP produced by the initiative was jointly created, the center built trust among participants and enabled them to develop new technologies, establish new business ventures in both markets, and gain additional support for technology demonstration projects.[28] Initiatives like CERC are needed to build and strengthen collaboration between U.S. startups and Chinese manufacturers while rhetoric coming from Beijing and Washington appears to be pursuing opposite goals.

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[27] Wang Hui, "Highest Damages Ever Awarded by Beijing IP Court and Stronger Patent Protection in China," *Patent Lawyer Mag*, (January/February 2017).
[28] Joanna I. Lewis, "Managing intellectual property rights in cross-border clean energy collaboration: The case of the US–China Clean Energy Research Center," *Energy Policy* 69 (2014): 546-554.

Concentrating investments in scaling current technologies can, of course, also threaten progress in leading-edge innovation. Technology lock-in through economies of scale and rapidly declining manufacturing cost can make it difficult for new economies to break into the market, even if they are both economically and technologically superior in the long-term. New battery chemistries, for instance, could in principle yield better performance, but have a hard time competing against established lithium-ion technologies currently produced at unprecedented scale in China. Many new solar technologies invented by U.S. startups similarly failed to reach the market in face of the cost advantage possessed by traditional silicon solar panels rolling off Chinese production lines.[29]

In the case of clean energy technologies urgently needed to reduce carbon emissions, however, the speed of technology deployment is critical. There is not enough time to wait for next-generation technologies to reach mass production. The world is well behind schedule on deploying the necessary 300 GW of renewable energy capacity every year from 2018 to 2030 to meet the goals of the Paris Agreement, in spite of the remarkable increases in renewable energy investment and the rapid cost reductions achieved by China. Likewise, the temporary emissions reductions caused by the Covid-19 pandemic and the associated economic shutdowns have not ushered the necessary structural changes we need to put the global economy on a more sustainable path. Instead, they have further fueled demand for economic decoupling and have undermined the premise of an economy integrated in global supply chains.[30] *The world simply does not have time to wait for the next generation of clean energy technologies, irrespective of where they are developed. Greater quantities of current LCETs can be immediately deployed*

[29] Varun Sivaram, John O. Dabiri, and David M. Hart, "The need for continued innovation in solar, wind, and energy storage," *Joule* 2, no. 9 (2018): 1639-1642.
[30] Diana Farrell, Susan Lund, Christian Foelster, Raphael Bick, Moira Pierce, and Charles Atlins, Mapping Global Capital Markets, In *Fourth Annual Report*: McKinsey Global Institute, McKinsey and Co., 2008.

with the existing capabilities of Chinese firms in mass manufacturing. The U.S. and Chinese government can and should work to make such collaboration less risky and establish a level playing field on both sides

Conscious Collaboration

The United States and China jointly account for 40 percent of global greenhouse gas emissions, putting these two nations at the center of any successful attempt to curb emissions to the levels required to prevent catastrophic climate change. Climate change is a global problem of unparalleled dimensions that requires a global response, including in the invention, commercialization, and production of technologies that can forge deep decarbonization. In the United States, some attribute China's rapid rise in LCET sectors to unfair industrial policies, such as forced technology transfer, subsidies, and outright intellectual property theft, aimed at strategically dominating the next generation of energy technologies. This common narrative is based on the mistaken assumption that the Chinese state is a monolithic actor when in fact different levels of government and administrative agencies have pursued different (and often conflicting) interests in the LCET industries. This misunderstanding has led to a series of misguided policy responses, including the ongoing tariff battles between the U.S. and China. Missing from this conversation is an understanding of Chinese manufacturers' critical contributions of knowledge and innovation to the global ecosystem of LCET development and commercialization.

We already have many of the technologies needed to begin making significant progress toward decarbonization, and recent cost reductions of solar and wind in particular mean that such progress is becoming ever more affordable. Collaboration was central to the development of contemporary renewable energy sectors, including collaboration between U.S. innovators and Chinese producers with skills in rapid scale-up and cost reduction. Trade battles and widespread talk of decoupling have begun to undermine the relationships needed to quickly and efficiently bring new technologies to market and deploy them at the scale required. If successful, such decoupling would thwart progress on decarbonization, making it highly unlikely that global warming can be contained to acceptable levels. Collaboration will continue to be central to rapid decarbonization to the deployment of clean energy technologies, and the U.S. and Chinese governments in particular should work to foster such collaboration. Initiatives like CERC are one promising path to achieving that goal.

Yet while the Biden administration has re-opened conversations with China on climate goal, not least urge China to step up its commitments under the Paris agreement, the economic relationship remains tense and mercantilist tendencies prevail. Domestic investments in clean energy industries are framed in the context of a competitive relationship with China and explicitly mention the reshoring of American jobs. Conversations between the United States and China, for now, remain focused on climate commitments, but neglect the tight linkages between the two economies that are central to producing the technologies required to meet climate goals.

Zero-sum approaches to the U.S.-China economic relationship obfuscate what the United States has to gain from collaboration. This is certainly true for U.S. renewable energy industries, which have suffered losses as a result of trade barriers to Chinese technologies first put in place under the Obama administration and were extended under Trump. It is important to note that such trade barriers have not brought manufacturing "back" to the United States. In LCET sectors, the removal of barriers and the restoration of open trade relationships is imperative to meeting global climate goals. Addressing grand challenges like climate change will require fundamental advances in technology, where the United States is uniquely equipped to be at the global frontier. In United States, this means continuing to support the core strengths of U.S. firms and universities—the invention of new technologies—through investments in basic and applied research. China is on course to overtake the United States in research and development spending in 2020 unless domestic efforts are ramped up. Particularly on climate-related technologies, the United States should accelerate its research and development investments to defend its technological lead.[31] Yet the technologies that emerge from these efforts must eventually be scaled and deployed, and for now, working with Chinese manufacturers can accelerate this process. Instead of competing with Chinese firms that have access to an institutional infrastructure supportive of mass production, U.S. renewable energy startups might have benefitted from working with Chinese partners instead of trying to be self-sufficient in an economy devoid of similarly supportive manufacturing institutions.

The division of labor between U.S. inventors and Chinese manufacturers is not fixed or inevitable. *Conscious collaboration with China entails working with and learning from Chinese partners on the development and deployment in LCET sectors, but it also comprises efforts to improve domestic competitiveness, including in segments of clean energy supply chains that are currently not well-supported in the U.S. economy.* The United States should continue to address attempts by China to discriminate against foreign firms and provide institutional support for domestic LCET firms trying to work with Chinese partners. It should also continue investing in domestic manufacturing capabilities as part of a national strategy for technological innovation. The creation of a domestic infrastructure bank that could finance domestic manufacturing projects, renewed investments in vocational training and technical colleges, and a stable

[31] Kelly Sims Gallagher and Zdenka Myslikova, "The Important Outcomes of Mission Innovation: First Evidence," Climate Policy Lab, September 8, 2020, https://www.climatepolicylab.org/climatesmart/2020/9/8/the-important-outcomes-of-mission-innovation-first-evidence.

regulatory framework to support domestic markets for clean energy technologies would improve national competitiveness in LCET sectors. This is especially important since China, too, continues to engage in techno-nationalism and to pursue national self-sufficiency in key technology areas.

Yet only long-term investments in domestic LCET industries will allow the U.S. to change the terms of its relationship with China in clean energy industries without jeopardizing global climate goals. Even then, it is unlikely that entire value chains for complex energy technologies would lie entirely within national boundaries. As trade conflicts between and China and the United States threaten to undercut efforts to strengthen global ties in local carbon energy industries, the United States should not lose sight of the climate challenge or risk *missing the narrow remaining window to sufficiently reduce global carbon emissions. Building on the advanced capabilities of Chinese firms in mass manufacturing is currently the most promising path toward rapid global decarbonization, but it does not preclude smart investments in domestic alternatives. For now, we cannot fix the climate crisis without collaboration with China.*