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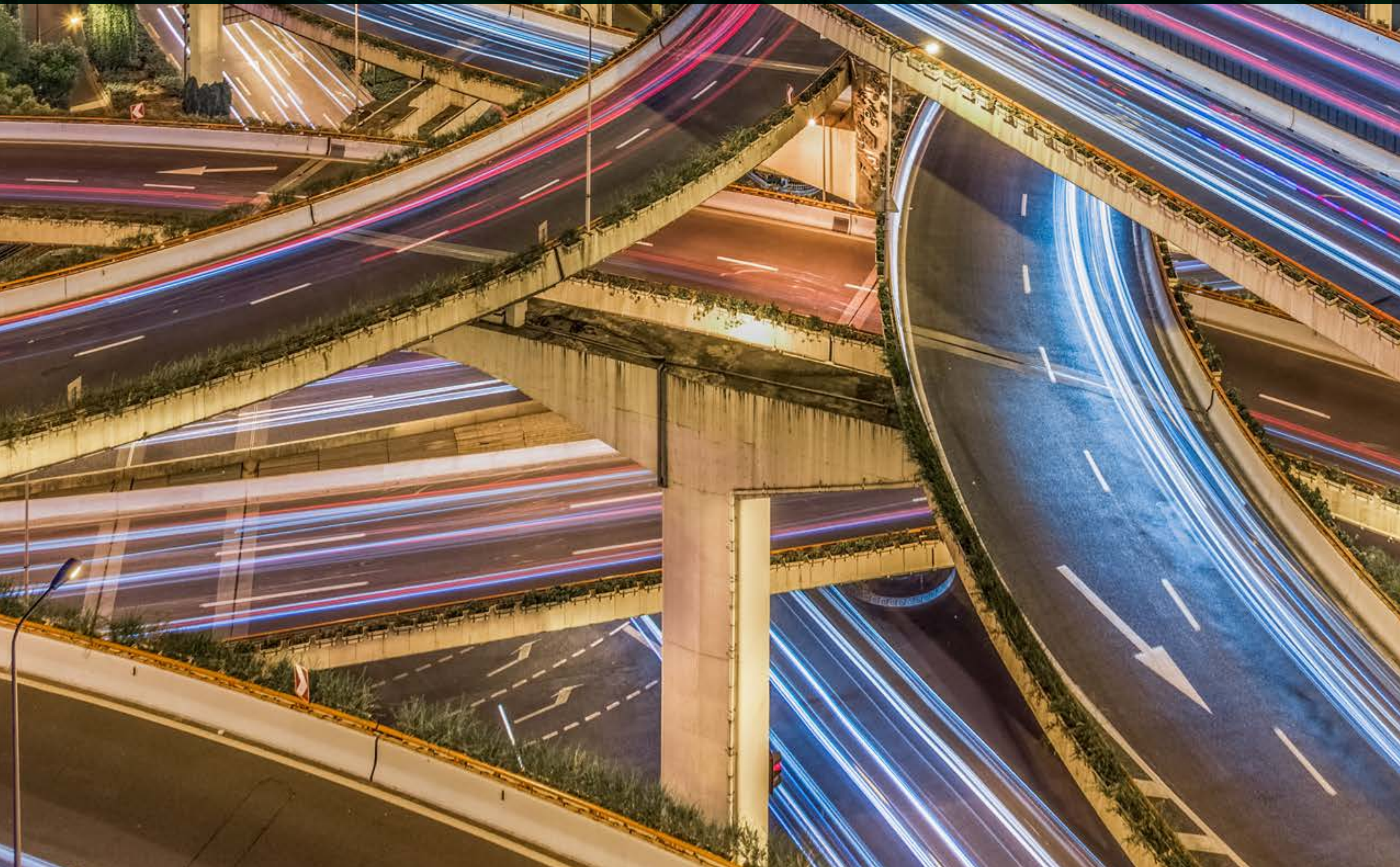
Publications

Accelerating Decarbonization in China and the United States and Promoting Bilateral Collaboration on Climate Change

November 2021



Introduction

In October 2021, Stanford University's Precourt Institute for Energy, Stanford Center at Peking University, and Shorenstein Asia-Pacific Research Center's China Program partnered with Peking University's Institute of Energy to organize a series of roundtables intended to promote discussion around how China and the United States can accelerate decarbonization and cooperate with one another to meet their carbon neutrality goals by mid-century. The thematic areas included U.S.-China collaboration on climate change, global sustainable finance, corporate climate pledges, and the opportunities and challenges for the acceleration of decarbonization in both countries in general, as well as specifically for the power, transportation, and industry sectors. The roundtable series brought together leading American and Chinese current and former officials, and experts in the public and private sectors working on energy, climate, the environment, industry, transportation, and finance. This report reviews the key themes and takeaways that emerged from the closed-door discussions. It builds on the "U.S.-China Joint Statement Addressing the Climate Crisis" released by the U.S. Department of State on April 17, 2021 and shares some common themes with the "U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s" released on November 10, 2021.[1] This report further identifies more concrete and additional promising areas for accelerated decarbonization and bilateral collaboration, as well as the obstacles to be tackled, including institutional, political, and financial constraints. This report could serve as a basis for concrete goals and measures for future U.S.-China cooperation on energy and the climate. It also highlights the contributions universities can make to the global energy transition.

The roundtable series identifies areas most critical or potent for bilateral collaboration, paving the way for concrete action plans at the national, local, and sectoral levels. Section 1 offers a brief overview of the acceleration of decarbonization in the U.S. and in China. Section 2 identifies the opportunities and challenges of U.S.-China cooperation on climate change. Sections 3-7 delve into specific promising areas for accelerated decarbonization and opportunities and hurdles for bilateral collaboration in corporate, finance, power, transportation, and industrial sectors.

This report is not a comprehensive review of all the relevant areas pertaining to decarbonization in China and the U.S. and bilateral collaboration on climate change. For example, this roundtable series focused on climate mitigation. Another strategy to respond to climate change is adaption, which we reserve for potential future discussion in a separate report. Additionally, the focus of this report is on energy. Important measures such as reforestation as a carbon sink are reserved for separate discussions. The views expressed in this report represent those of the participants at the roundtable series and do not necessarily represent the positions of the organizing institutions. Chatham House rules were used throughout the roundtables to facilitate open and frank discussion, so views are not attributed to individual participants.

1 U.S. Department of State (2021, April 17). *U.S.-China Joint Statement Addressing the Climate Crisis*. Retrieved November 10, 2021, from https://www.state.gov/u-s-china-joint-statement-addressing-the-climate-crisis/.
U.S. Department of State (2021, November 10). *U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s*. Retrieved November 10, 2021, from https://www.state.gov/u-s-china-joint-glasgow-declaration-on-enhancing-climate-action-in-the-2020s/.

Convenors

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The mission of Peking University's Institute of Energy is to build a pioneering and distinctive platform focusing on interdisciplinary innovation, competitive curriculum and comprehensive research of policy and energy sciences. The institute aims to accelerate the innovations of energy technology, promote clean energy transition, develop specialized and public education, build an energy think-tank and a platform for clean energy research and promotion at the international level.

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The China Program at Stanford's Shorenstein Asia-Pacific Research Center is the University's hub of scholarship on current political, economic, and social transformations in China and the implications of its rise for the global community. Our goal is to prepare new generations of Stanford students for deeper interactions with China and to share knowledge of China with the broader community. We do this by conducting research and organizing conferences and intellectual exchanges with Chinese experts, extending on-campus and in-country training opportunities for Stanford students and scholars, hosting public forums on Greater China, and offering educational programs for government officials and professionals.

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Located on the Peking University campus in Beijing's vibrant Haidian District, the Stanford Center at Peking University (SCPKU) is a focal point for building academic and educational networks throughout East Asia. Its mission is to expand Stanford's role in global education and research to China. The tri-level center offers collaborative spaces, offices, event support services, and funding for innovative research and education. SCPKU brings together established researchers and a new generation of young scholars to create a dynamic hub of intellectual exchange and collaboration. The Center accelerates the flow of people, ideas, research, scholarship, and training aimed at benefiting both China and the U.S.

STANFORD PRECOURT INSTITUTE FOR ENERGY

Stanford's Precourt Institute for Energy leads Stanford University's broad and deep efforts to help create a future of sustainable, affordable and secure energy for all people. The Precourt Institute funds an extensive portfolio of energy research. It has launched Stanford research initiatives on energy storage, sustainable finance, electric grid modernization and natural gas, as well as on environmental and energy policy. The institute supports courses and internships for students and contributes to energy literacy. It also is a major contributor to building the energy transition ecosystem on campus and around the world.

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Abbreviations

Asset-Backed Securities (ABS)

Artificial Intelligence (AI)

Artificial Intelligence of Things (AIoT)

Carbon Sequestration and Storage (CSS)

Carbon Capture, Utilization, and Storage (CCUS)

Distributed Energy Resources (DER)

Department of Energy - USA (DOE)

Department of Justice - USA (DOJ)

Environmental, Social, and Governance (ESG)

Electric Vehicle (EV)

Federal Energy Regulatory Commission - USA (FERC)

Heating, Ventilation, and Air Conditioning (HVAC)

Internet of Things (IoT)

Liquefied Natural Gas (LNG)

Ministry of Industry and Information Technology - China (MIIT)

New Energy Vehicle (NEV)

Power Usage Effectiveness (PUE)

Photovoltaic (PV)

Renewable Energy Certificate (REC)

Real Estate Investment Trust (REIT)

Sustainable Finance Disclosure Regulation (SFDR)

Special Purpose Acquisition Company (SPAC)

Task force on Climate-related Financial Disclosures (TCFD)

Vehicle-to-grid (V2G)

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Executive Summary

Below are the key takeaways from the discussions:

- Our goal should be to have sustainable, affordable, reliable, and resilient energy for all.
  - The energy transition period is critical and challenging, as shown in recent rolling blackouts in Texas and parts of China. We need to create resilient energy systems in the face of increasing climate risks.
  - Until we have mass-scale, long-duration energy storage in place to address challenges posed by intermittent generation, diversification in energy resources is necessary.
  - We should also aim for a just transition, where the financial burdens, as well as benefits of decarbonization, are equitably distributed.
- Creating shared regulatory frameworks and standards would make trade, validation, accounting, climate pledge fulfillment, and ESG evaluation easier to implement.
- Political and institutional constraints are obstacles to meeting carbon reduction pledges. Therefore, support from central and local governments will be critical. We need to understand who the relevant actors are and what incentives they face in policy making and implementation, especially in the period when consensus around goals and priorities has not fully formed.

- Rigorous R&D programs are needed to manage the energy transition with minimal economic disruption. The experts identified the following promising R&D areas, listed in no particular order:
  - Heat pumps for heating, ventilation, and air conditioning
  - More energy-efficient buildings
  - Low-carbon cement, steel and construction
  - Low-carbon agriculture
  - Carbon capture, utilization, and storage (CCUS)
  - Power grid modernization
  - Long-duration energy storage
  - Methane leakage prevention and atmospheric methane removal
  - Electrification of Transportation
  - Renewable Fuels
- Tensions in U.S.-China relations have hindered the acceleration of decarbonization. Open science in fundamental research must be encouraged. Universities can educate future leaders, advance knowledge, and foster U.S.-China collaboration on open-science R&D, regardless of the political environment. The roundtables identified six areas where the U.S. and China could collaborate:
  - Global green finance
  - Carbon capture, utilization, and storage
  - Low-carbon agriculture and food processing
  - Methane leak reduction
  - Grid integration and greater use of intermittent renewables
  - Governance, including at the subnational level

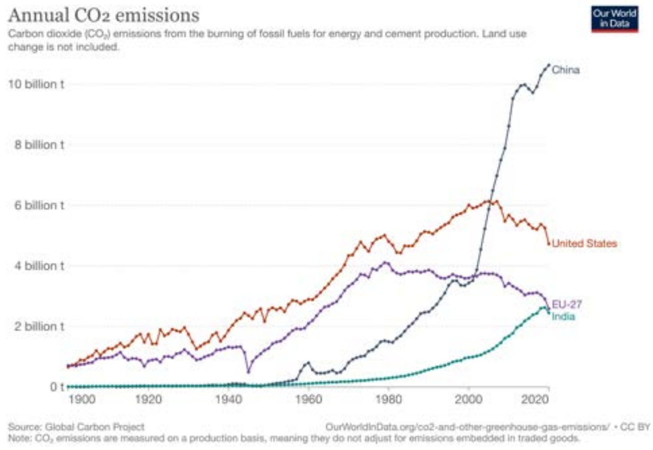
- Strong and resilient supply chains are critical to decarbonization, including for example the production of batteries and solar power equipment. Current problems point to the need for greater coordination among countries, especially between China and the U.S. Establishing and implementing shared frameworks and standards could create a global supply chain more conducive to the trade of low-carbon products and technologies.
- In response to demand for sustainability from consumers, many large corporations have made significant pledges to reduce emissions. Technologies in three areas will be critical to corporations' ability to deliver on their pledges:
  - Electrification
  - Digitization
  - Carbon capture, utilization, and storage

- Broadly, the most promising strategy to decarbonize energy is to electrify consumption now served by fossil fuels as much as possible while decarbonizing electricity generation. Maintaining grid reliability and resilience while decarbonizing the power sector is extremely important. To vastly expand electricity use while maintaining or improving reliability requires research and collaboration in renewable supply forecasting, demand flexibility, digitization, intelligent controls, long-duration storage, and low-carbon resources and carriers.
- The following challenges exist for EV development in both countries: infrastructure, pricing models and regulatory policies regarding distributed energy resources (DERs), and tariffs and supply chains.
- To decarbonize industry, production and manufacturing processes must be made more energy-efficient. In addition, hydrogen production from solar energy (i.e., green hydrogen) is promising for decarbonizing industry. However, we should think about unintended consequences and the circular economy from the onset.
- In the spirit of the recent "U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s," this series of roundtables can serve as a model of bilateral exchange, especially when sponsored by universities. Future such discussions are needed to develop concrete net-zero action plans by economic sector.

Accelerating Decarbonization in the U.S. and in China

Climate change is a borderless issue that will likely define the 21st Century, involving energy, agriculture, infrastructure, security, and a wide range of other aspects of life. The goals of pursuing economic growth, energy mix, and environmental sustainability (3 Es) must go hand in hand. China and the United States are the two biggest carbon-emitting countries in the world (Figure 1); decarbonization in these two countries will have material impacts on a global scale and is timelier than ever. We are embarking on a once-in-a-century transition.

FIGURE 1: COUNTRY/REGION CARBON DIOXIDE EMISSIONS, 1900-2020



Decarbonization and the transition from fossil fuel-based energy systems to clean ones is a tremendous task. It will require massive economic and political change, technological innovation and the scale-up of its application, as well as a fundamental reevaluation of established growth models. Such change should be pursued as rapidly as we can make it (and faster than the pace now) with the understanding that it has to be coordinated in such a way that the demand for energy services and their reliability must be met as the transition to lower GHG emissions takes place. Recent episodes in the U.S. that exposed the vulnerability of the current electricity system to extreme weather events are the blackouts in California and in Texas. In August 2020, California suffered its first rolling blackout since the 2000-01 energy crisis that left millions without power because system planners phased out gas plants without ensuring battery-based storage was in place as backup. The situation was exacerbated due to a heatwave that raised energy demand. In February 2021, unexpected storms froze up wind turbines and inadequately winterized gas-fired power plants fell short in supplying heat and electricity in Texas.

While developed countries enjoy a relatively long period to achieve their carbon emissions peaks, having transitioned years ago from industrial to service-based economies, China has a much shorter timeline. With growing energy consumption and carbon emissions, China faces the heightened challenge of decarbonizing while ensuring energy security to its vast populace. Recent energy shortages in China have affected global economic forecasts, supply chains, and beyond. Hence, we need to establish well-developed new energy alternatives in order to depart from existing policies, with the goal of **promoting a sustainable, affordable, and secure energy supply for all**. A one-size-fits-all approach in regulating energy supply and demand is unlikely to work well.

Rigorous R&D programs are needed to effectively manage the clean energy transition while minimizing disruptions. Some promising areas are included below, listed not in any particular order. We also need to think about how these R&D programs fit with energy and market systems so that new technologies will not cause price spikes or supply disruptions.

- **Heat pumps for heating, ventilation, and air conditioning (HVAC)**: Electric heat pumps could drastically reduce household energy consumption when they are used to replace gas-powered appliances. In addition to their superior energy efficiency compared to gas furnaces, heat pumps would have an increasingly positive effect on emissions reductions over time, as the electricity grid continues to shift towards generation based on renewables.[1]
- **More energy-efficient buildings**: Cities are the source of more than 70 percent of China's carbon emissions, and almost one-third of those emissions originate from the heating, cooling, and electricity supply for large buildings.[2] In the U.S., fossil fuel use from residential and commercial buildings makes up about 29 percent of total greenhouse gas emissions. Thus, curbing buildings' energy consumption would significantly reduce emissions in both countries.[3]
- **Low carbon cement, steel and construction**: Cement manufacturing has been estimated to cause up to 8 percent of total emissions worldwide. Alternative manufacturing methods – such as changes in the "recipe" of materials and processes used in production, to inventive strategies, including carbon capture and incorporation of carbon-absorbing bacteria into the mix – may help to reduce the tremendous share of emissions produced by cement manufacturing.[4]
- **Low-carbon agriculture**: It has been estimated that the agricultural sector contributes to 10-12 percent of global emissions of carbon dioxide equivalents (CO2e). China is a major player in global farming, and the agricultural sector is accountable for a significant proportion of its emissions. Reduced application of nitrogen fertilizer and improved management of agricultural waste, such as crop straw, can be key.[5]

1 McKenna, C., Shah, A., & Silberg, M. (2020). *It's Time to Incentivize Residential Heat Pumps*. Rocky Mountain Institute. https://rmi.org/its-time-to-incentivize-residential-heat-pumps/.

2 Natural Resources Defense Council. (2017, June 1). *Promote energy-efficient buildings in China*. NRDC. https://www.nrdc.org/issues/promote-energy-efficient-buildings-china.

3 Leung, J. (2020, February 4). *Decarbonizing U.S. buildings*. Center for Climate and Energy Solutions. Retrieved October 19, 2021, from https://www.c2es.org/document/decarbonizing-u-s-buildings/.

4 DiChristina, M. (2020, November 10). *Low-carbon cement can help Combat Climate Change*. Scientific American. Retrieved October 20, 2021, from https://www.scientificamerican.com/article/low-carbon-cement-can-help-combat-climate-change/.

5 Cheng, K., & Pan, G. (2021, February 12). *How can China cut emissions from its farms?* China Dialogue. Retrieved October 20, 2021, from https://chinadialogue.net/en/food/how-can-china-cut-emissions-from-its-farms/.

- **Carbon capture, utilization, and storage (CCUS)**: Experimental technologies are being tested to directly remove carbon dioxide from the air around them, which can then be used for other purposes or stored underground. According to the U.S. Geological Survey, the U.S. possesses 2,400 to 3,700 metric gigatons of potential carbon dioxide storage under current engineering capabilities.[6] However, CCUS installations currently require high amounts of energy to operate, which means that carbon capture solutions will have to be pursued in tandem with increased accessibility of renewable power in order to maximize emissions reductions.

- **Power grid infrastructure upgrades**: More than half of significant power outages in the U.S. during 2000-2016 resulted from extreme weather events like hurricanes, wildfires, and heatwaves. The aging power grid system is not built to withstand such hazards intensified by climate change. One feasible solution is to build distributed microgrids, which are powered by solar panels in case of interrupted supply from the power company.

- **Long-duration energy storage**: Over 90 percent of large-scale battery storage capacity in the U.S. was provided by batteries based on lithium-ion chemistries. Beyond lithium-ion batteries, we also need to advance other long-duration storage technologies to decrease the need for building peak power plants. U.S. DOE's Energy Storage Grand Challenge aims to develop and domestically manufacture energy storage technologies that will meet all market demands by 2030, with the 5¢/kWh levelized cost target for long-duration stationary applications[7]. China aims to launch more than 62 gigawatts (GW) of pumped hydro storage in 2025 and 120 GW in 2030, while establishing globally competitive companies that use this advanced technology as industry leaders by 2035[8].

- **Methane leakage prevention and removal**: methane is a potent greenhouse gas -- having 25 times the warming impact as carbon dioxide over 100 years -- and is responsible for about a third of recent global warming. In October 2021, the U.S. and the E.U. led the Global Methane Pledge to collectively reduce methane emissions by at least 30 percent by 2030, based on 2020 levels. A major part of the COP26 was dedicated to reducing methane emissions. For instance, the Biden administration announced a methane initiative that includes new EPA regulations to reduce methane leakage in the oil and gas industry, among other actions. Methane removal, or atmospheric methane oxidation to carbon dioxide, is another promising R&D area. A recent study led by Stanford researchers shows that if methane removal technologies are deployed at scale, we could prevent 0.4 degrees of warming by 2050.[9]

6 U.S. Geological Survey (2013). *National Assessment of Geologic Carbon Dioxide Storage Resources—Results.* USGS. https://pubs.usgs.gov/circ/1386/pdf/circular1386.pdf.

7 U.S. Department of Energy (2020, December 21). Energy Storage Grand Challenge Roadmap. Retrieved November 5, 2021, from https://www.energy.gov/energy-storage-grand-challenge/articles/energy-storage-grand-challenge-roadmap.

8 China National Energy Administration (2021, September 9).《抽水蓄能中长期发展规划（2021-2035年）》印发实施 - 国家能源局. Retrieved November 5, 2021, from http://www.nea.gov.cn/2021-09/09/c_1310177087.htm

9 Jackson, R. B. et al. (2021). *Atmospheric methane removal: a research agenda*. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. https://royalsocietypublishing.org/doi/10.1098/rsta.2020.0454.

- **Electrification of transportation**: The transportation sector is one of the biggest GHG-contributing sectors in both the U.S. and China. There has been a global effort to electrify transportation and localize infrastructure for EV development. A surge in lithium-ion battery production has led to an 85 percent decline in price, making EVs commercially viable for the first time in history. In August 2021, President Biden outlined a target of 50 percent EV sales share in 2030.[10] Similarly, the State Council of China imposed a mandate on automakers, requiring 40 percent EV sales share by 2030.[11] Such deep electrification goals in the U.S. and China require R&D on, investment in, and deployment/implementation of appropriate battery technologies, management systems, autonomous technologies, and charging infrastructures.

- **Renewable fuels**: Aviation, maritime transport, and heavy industry sectors are hard to electrify. Renewable fuels such as biofuel and green hydrogen fuel are thus very important to decarbonizing these sectors. The Biden Administration set the goal to produce three billion gallons of sustainable fuel and to reduce emissions from aviation by 20 percent by 2030.[12] [3]

10 The White House (2021, August 5). FACT SHEET: President Biden Announces Steps to Drive American Leadership Forward on Clean Cars and Trucks. Retrieved December 7, 2021, from https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/05/fact-sheet-president-biden-announces-steps-to-drive-american-leadership-forward-on-clean-cars-and-trucks/

11 State Council (2021, October 24). Carbon Peak by 2030 Action Plan. Retrieved December 7, 2021, from http://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm.

12 The White House (2021, September 9). FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation. Retrieved December 7, 2021, from https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation/.

Opportunities and Challenges for U.S.-China Cooperation on Climate Change

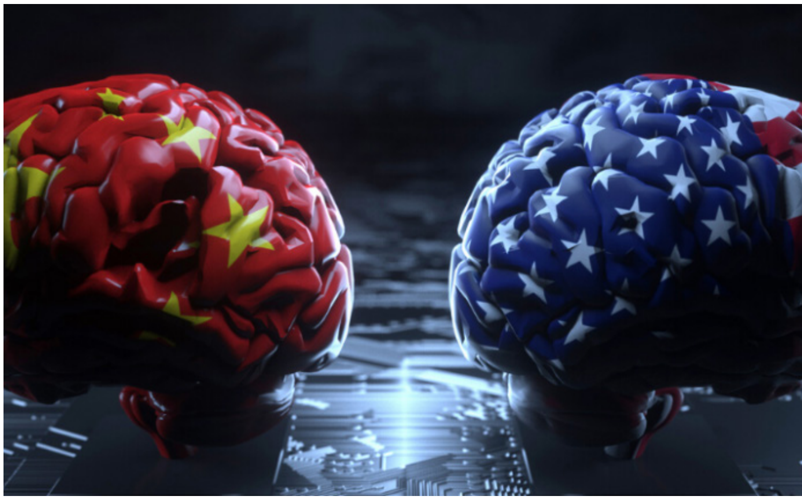
In addition to domestic efforts to decarbonize the economy, the collaboration between China and the U.S. can help accelerate that process. While competition between China and the U.S. is to be expected and can be good, if it is fair, U.S.-China cooperation on energy and climate issues benefits not only both countries but also the world at large. In spite of the recent friction in bilateral relations, the two countries can and must collaborate on energy and climate issues to achieve the 1.5-degree climate goal, even if they disagree on other issues.

The U.S. and China have their own comparative advantages in their efforts to decarbonize. We list a few examples here. In solar energy development, the U.S. first developed solar PV technologies, while China invested heavily in them and made solar PV scalable. In energy storage, China has built extensive pumped hydro storage and will continue to build more. In containing emissions from raising cattle, U.S. companies have been successful in developing alternative meat for Beyond Meat and Impossible Burgers.

The experts at the roundtables identified six specific areas that the U.S. and China could collaborate on:

1. Global green finance
2. Carbon capture, utilization, and storage
3. Food systems and climate change
4. Methane leak reduction
5. Grid integration of renewables
6. Governance, including at the subnational level

So far, the third area, food systems and climate change, has not received enough attention. The food system contributes to 34 percent of global carbon emissions, and climate change has devastating effects on food systems.[13] Cutting food waste can help.



The fourth area, methane leak reduction, is of increasing salience, as China ramps up natural gas to displace coal. Methods for detecting leaks is an emerging and promising area of collaboration. The U.S. and China can work together to both bring down the costs of the various technologies and scale up those technologies. Moreover, U.S.-China collaboration will be key for U.S. export of liquefied natural gas (LNG) to China. A promising recent happening is Venture Global LNG's signing of two 20-year offtake contracts with Sinopec for a total supply of 4 million mt/year, representing by far the biggest volume in a U.S. LNG contract with a single Chinese entity.[14]

13 Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). *Food systems are responsible for a third of global anthropogenic GHG emissions*. Nature Food. https://www.nature.com/articles/s43016-021-00225-9.

14 Weber, Harry (2021, October 19). *Venture Global agrees to sell 4 million mt/year of LNG to China's Sinopec: DOE*. Retrieved November 22, 2021, from https://www.spglobal.com/platts/en/market-insights/latest-news/lng/101921-venture-global-agrees-to-sell-4-million-mtyear-of-lng-to-chinas-sinopec-doe.

Last but not least, cooperation should not be confined to the technological sphere; we need cooperation on governance as well. To expand the deployment of renewable technologies, institutional factors can play a major role and that will be key to overcoming powerful interest groups like fossil fuel companies. We should also aim for a just transition, where the financial burdens as well as benefits of decarbonization are equitably distributed.

In addition to collaboration between the two national governments, collaboration could also happen at the subnational level. On this front, climate collaboration between California and China is a good example, particularly because it has persisted despite recent U.S.-China tensions. Partly as a way to pursue climate action despite legislative gridlock on the national level, California has formally engaged with Chinese leaders and cities to share knowledge, tools, and technology. For example, the California-China Urban Climate Collaborative was established so that a network of cities in both geographic areas can work together to address the climate crisis through research, policy, and advocacy. In a 2017 visit to China, then-California Governor Jerry Brown formally established partnerships between California and Chinese provinces, universities, and government ministries to expand innovation and cooperation in meeting climate goals.

While some progress has been made in the past, major hurdles have emerged and need to be tackled for continued and meaningful collaboration. Theft of proprietary U.S. intellectual property by some Chinese companies has been problematic. The National Bureau of Asian Research's Commission on the Theft of Intellectual Property estimates that U.S. companies suffer a loss of between USD 225-600 billion annually due to intellectual property infringement in China.[15] This is a major hindrance in U.S.-China cooperation because R&D is critical. On this point, it is important to distinguish between fundamental research and proprietary research. Proprietary research, by definition, should receive due protection. But fundamental research should be pursued under terms of academic freedom, especially within universities.

Open science should and must be followed when it comes to fundamental research. Unfortunately, the U.S. Department of Justice's China Initiative has wrongly prosecuted some U.S.-based scholars for intellectual espionage when they were conducting fundamental research with China-based collaborators and institutions.[16] China and the U.S. should aim to rebuild trust, continue and strengthen open science collaboration, and control theft of proprietary knowledge. Award programs can be set up for sustainable innovators and the buying and sharing of sustainable technologies. On the bright side, we do have people in the U.S. and China who understand each other. American and Chinese students increasingly choose to receive further education on the other side of the Pacific. That is a good starting position and can set the tone for cooperation for future generations.

In the broader scheme, U.S.-China climate talks have, so far, remained very high-level, without concrete, sector-specific collaboration. We need a clear roadmap with working groups supported by governments and sector-specific collaboration.

15 United States Trade Representative (2018). *Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation under Section 301 of the Trade Act of 1974*. USTR. Retrieved October 21, 2021, from https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF.

16 Nakashima, E., & Nakamura, D. (2021, September 15). *China Initiative aims to stop economic espionage. Is targeting academics over grant fraud 'overkill'?* The Washington Post. Retrieved November 3, 2021, from https://www.washingtonpost.com/national-security/china-initiative-questions-dismissals/2021/09/15/530ef936-f482-11eb-9738-8395ec2a44e7_story.html.

Global Sustainable Finance

It is important to recognize that none of the desirable technologies or policies will materialize without enough funding raised for them and wisely spent. Some may think that technology and policy are hard to do and that investments are easier to do. That is not necessarily the case. In finance, despite substantial expressed will to address climate change in recent years, there has been limited action to date. How can we make the state of global sustainable finance more conducive to achieving net-zero emissions? Three points stand out.

First, the U.S. and China can collaborate on standard-setting, especially accounting and validation standards. Second, we need to develop more mechanisms to facilitate green finance. In particular, we need more corporate bonds and equity investments. We also need finance and mechanisms to help scale up new technologies. Finally, there are important nuances to consider in the low-carbon transition, such as the unique circumstances of each country, the smooth downsizing of high-carbon industries, the equitable distribution of benefits and costs among individuals and regions.

To reach carbon neutrality, at least 3.0-3.3 trillion RMB investments are needed on a yearly basis in China.[17] At present, the available money to fund the transitions are 95 percent credit loans, 2 percent corporate bonds, and 3 percent equity investments. Higher percentages could come from corporate bonds and equity investments. China needs to develop more tools to facilitate green finance.

Climate finance is currently active globally across four fora, involving various institutions:

17 Chen, B., Faeste, L., Jacobsen, R., Kong, M. T., Lu, D., & Palme, T. (2021, September 21). *How China can achieve carbon neutrality by 2060*. BCG Global. Retrieved October 20, 2021, from https://www.bcg.com/publications/2020/how-china-can-achieve-carbon-neutrality-by-2060.

1. **Multilateral negotiations:** Multilateral negotiations will start picking up soon, including discussions on finance mobilization, loss and damages, offsets, funds for equitable transition, compensating border adjustments, among others.
2. **Green finance:** Building low-carbon infrastructure has been successful, bringing about competitive renewables pricing. It is easier to go green when building new infrastructure. While building new and green is good, the question is how much a country can build, especially under weak macroeconomic conditions with low demand.
3. **Climate risk:** There has been growing attention on climate risk. How can we wind down high-carbon systems in a stable, efficient, and equitable way? There has been sharp development in solutions for addressing physical climate risk, as reflected by innovation in the insurance industry. However, solutions for addressing transition risks have been slower. New financial instruments are on the horizon to reach markets and manage those risks.
4. **Net zero:** There have been a lot of decentralized actions in reaching net-zero targets. Such actions are built on financial regulation and investor confidence, as it is about disclosure, commitments, and reporting. A worthwhile question is how to develop credible transition plans.

Climate finance is increasingly popular in China thanks to the current administration targeting decarbonization. Many new funds and financial instruments, including the "carbon neutrality bonds" introduced this year to help finance sustainable projects, are emerging at an accelerating pace.[18] Balance of green loans in China is up 27 percent year-on-year, and the green bond market is under rapid development as well. The latest balance is at 700 billion RMB, with almost 270 billion RMB issued in the past year. The first real estate investment trust (REIT) asset backed security aimed at carbon-neutral outcomes was recently approved, and several private equity funds with government support have also been established. Finally, we are seeing platforms for carbon trading starting to emerge.

Internationally, President Xi announced via a pre-recorded video address at the UNGA meeting in September 2021 that China would not build new coal plants abroad. In the same speech, he said that "China will step up support for other developing countries in developing green and low-carbon energy. John Kerry, the first and current United States Special Presidential Envoy for Climate, quickly reacted, calling the announcement a "great contribution," and added that "[they have] been talking to China for quite some period of time about this. And [he is] absolutely delighted to hear that President Xi has made this important decision."[19] Greening infrastructure financing in recipient countries shows that U.S.-China cooperation could happen in third countries.

In the global financial community, there has been a gradual awakening about climate change. Corporations are setting targets to minimize carbon emissions impact from their business models, but policies and regulations are needed to incentivize and enforce behaviors. Europe has been very active on this front, with the Sustainable Finance Disclosure Regulation (SFDR) and the Task Force on Climate-related Financial Disclosures (TCFD), asking corporations and fund managers to disclose carbon footprints and roadmap for attaining net-zero carbon emissions. For instance, Deutsche Bank DWS seeks corporations and fund managers that support

18 Reuters Staff. (2021, February 9). *China's first "carbon neutrality" bonds draw tepid demand*. Reuters. Retrieved October 20, 2021, from https://www.reuters.com/article/china-bond-green/chinas-first-carbon-neutrality-bonds-draw-tepid-demand-idUSL4N2KF1O1.

19 Reuters Staff (2021, September 22). *In climate pledge, Xi says China will not build new coal-fired power projects abroad*. Reuters. Retrieved November 17, 2021, from https://www.reuters.com/world/china/xi-says-china-aims-provide-2-bln-vaccine-doses-by-year-end-2021-09-21/.

climate change initiatives and offset carbon footprints. They see the most opportunities in countries with high emissions and in developing countries where new infrastructure is being built. Energy, water, and waste are the three focus areas because the metrics are readily quantifiable, making it easier for investors to hold corporations accountable.

Generally speaking, an organization working to reduce their emissions footprint can resort to a variety of options, including reducing their direct emissions (i.e., emissions from sources the organization directly owns or controls), lowering their indirect emissions (i.e., emissions caused by the activities of the organization but occur at sources owned or controlled by another organization), by pursuing energy efficiency measures or switching to green power, and paying for external reductions of emissions.

However, there are challenges. **First, a real challenge exists in measuring and tracking emissions.** Particularly, it is important to establish a mechanism to guard against double counting – a situation where two parties claim the same climate action, be it carbon removal or emissions reduction. This is so that the renewable energy certificate (REC) – a tradeable instrument that represents the legal property rights to "renewable-ness" in renewable electricity generation – can be correctly attributed to those for their carbon-offset efforts. To facilitate the flow of capital, we need to ensure that investments have measurable outcomes that can be traced and verified by third parties. Countries like the U.S. and China can collaborate in creating standards on accounting and validation.

Second, related to measurement, a big challenge is in setting standards, especially shared standards. For example, we need more consistent and comparable standards for environmental, social, and governance (ESG) providers. Currently, there is no universally accepted definition of "green" or "sustainable" finance, leading to a proliferation of investment holdings that bill themselves as "green" but have dubious environmental impacts.[20] However, given the imbalanced development across regions, it would not be feasible to roll out a single standard at once; we may need to allow more time for multiple standards to coexist first.

Third, soft assets have been overlooked in current considerations. Companies that invest in soft assets like R&D, which contributes to quickening the pace of transition, face the challenge of not being able to readily get credit. This aspect tends to be often-overlooked because we tend to focus on physical facilities rather than the efficient systems that involve soft assets. Much clean energy and climate change-related research is financed or conducted by government agencies such as the Department of Energy, NASA, and the United States Geological Survey. Greater incentives for private investments in new technologies and climate solutions would accelerate the low-carbon transition and encourage economic stability, as companies will be able to better avoid climate-related business disruptions.[21]

Fourth, policy uncertainty prohibits green finance flows at the moment. We need bilateral governments to encourage cross-border green capital flow. China-Europe collaboration on this front has been advanced through discussions among heads of state. That helps send a strong signal to companies because that provides policy certainty. Between the U.S. and China, if we can establish a similar green partnership, then it will be easier for us to get into more specific topics like Special Purpose Acquisition Companies (SPACs), green Asset-Backed Securities (ABS), among others, and establish working groups. To bring existing technologies to scale, we need to speed up financing. While Stanford and the greater Silicon Valley ecosystem have many venture capital funds, a question remains as to how to scale up afterwards. More policy certainty will help.

There may be more room for collaboration on net-zero emissions and reducing overall climate risk, where fewer barriers are involved. A potential collaboration could focus on creating transition plans compatible with net-zero goals. Opportunities are present for early-stage development in carbon removal, food protein and synthesis, and heating. These can go through commercialization and scale-up through the net-zero and climate risk structures than through the green tech structure.

20 Landberg, R., Massa, A., & Pogkas, D. (2019, June 7). *Green Finance Is Now $31 Trillion and Growing*. Bloomberg. Retrieved October 20, 2021, from https://www.bloomberg.com/graphics/2019-green-finance/.

21 Goldstein, A., Turner, W. R., Gladstone, J., & Hole, D. G. (2018, December 10). *The private sector's climate change risk and adaptation blind spots*. Nature. https://www.nature.com/articles/s41558-018-0340-5.

Corporate Climate Pledges

In 2019, Amazon and Global Optimism co-founded The Climate Pledge initiative – a platform for businesses to sign on, declare, and implement ambitious plans to achieve net-zero carbon emissions by 2040 – 10 years ahead of the goal set by the Paris Agreement. So far, 60 percent of Fortune 500 companies have made climate pledges. More than 200 companies have committed to achieving carbon neutrality by 2040. Additionally, companies like Google are committed to completely decarbonizing their electricity supply and operating on 24/7 carbon-free energy (i.e., having operations consistently powered by energy resources that do not emit greenhouse gases) everywhere by 2030. These climate pledges will drive forward the net-zero transition on the demand side. The demand side is crucial in order to achieve lasting decarbonization. We need to ensure consumption of renewable power to complement increased generation capacity.

Nationally, measures have been put in place to make it easier for companies to fulfill their climate pledges. For example, in September 2021 China launched a pilot program that would allow consumers to directly purchase renewable-generated electricity from power-generating utilities for the first time. Before that, consumers could only purchase green electricity generated by generators through the two state-owned grids – State Grid and China Southern Power Grid. On the first day the platform opened, 262 companies traded 10.9 billion kWh of green electricity.

However, while companies are making climate pledges, those pledges can vary significantly in terms of substance, scale, and speed. For example, Microsoft's climate pledge is substantial, and the company sees delivering on it as almost existential. Microsoft has committed to becoming carbon-negative – removing more carbon than it emits each year – by 2030. By 2050, Microsoft will remove from the atmosphere all the carbon the company has emitted both directly and via the supply and value chain since its founding in 1975. This carbon-negative commitment covers all three scopes of emissions: Scope 1 emissions are created directly from vehicle fleets and diesel-generated backup power for operations at data centers; Scope 2 emissions are associated with energy consumption; Scope 3 emissions are related to upstream supply chain and downstream consumption like Xbox users. The company still faces challenges in terms of reducing Scope 3 emissions. In 2020, it extended its internal carbon fee, or carbon tax, to include Scope 3 emissions. The carbon fee was introduced in 2012 and was raised to $15/ton in 2019. It has also launched a $1 billion Climate Innovation Fund to expedite the global development of carbon reduction, capture, and removal technologies. As a donor, it established a $100 million grant to Breakthrough Energy Catalyst, a public-private partnership, which has initially focused on four areas for innovation: direct air capture, green hydrogen, long-duration energy storage, and sustainable aviation fuel.

Chinese companies are lagging a bit behind their overseas counterparts in making and implementing plans to reduce carbon emissions. President Xi's announcement that China as an entire nation will become carbon-neutral by 2060 evidently sent a strong signal to corporations, as several Chinese companies began announcing climate plans soon after. For instance, in January 2021, Tencent – one of the world's biggest Internet companies and owner of the WeChat app – announced a plan to achieve carbon neutrality. As proposed, it will take four steps: 1) understand its emissions inventory; 2) design its pathway to achieve carbon-neutrality; 3) implement the plan; and 4) verify its reported performance. So far, Tencent has completed the first step, finding that its carbon emissions are about equivalent to those of a mid-sized coal power plant. About 80 percent of those emissions are due to electricity consumed by its data centers. Since

data centers are growing, they should be an area of focus for emissions cuts. Tencent is currently developing pathways and strategies and expects to release a more concrete plan by the end of this year. Tencent is also making immediate efforts, such as participating in green power trading that started in September 2021, certifying headquarter office buildings for energy efficiency, and supporting reforestation to produce "carbon sinks". In the grand scheme of things, Tencent also hopes to help the entire industry achieve carbon neutrality with the support of its energy-saving technologies. Already, Tencent has deployed liquid cooling technology to reduce power usage effectiveness (PUE) – a ratio of total power use versus power used to run IT equipment, with the closer the value to 1, the more efficient – down to 1.06 at its data center in Qingyuan City, Guangdong Province.

One of the biggest challenges for China to achieve carbon neutrality rests in its electricity grid. As a representative from one of China's largest power generation firms put it, "we need to start our business for the second time." First, there is a need to retrofit existing plants for ultra-low emissions. Second, there need to be huge investments made to deploy renewables and new technologies into the grid. Companies are slowly taking steps in this direction: in January 2021, their company announced its plan to develop 80 GW in additional clean energy power capacity by 2025.

Corporations also play a big role in decarbonizing the global supply chain. First, companies need to see themselves as part of the global supply chain. The easiest and fastest way to decarbonize the global supply chain is for corporations to take ownership of their Scope 3 emissions. For instance, Microsoft's internal carbon fee applies to Scope 3 emissions, including those from the supply chain. In practice, when the company puts out a Request for Proposal (RFP) to procure goods, there will be a certain number of bids. Traditionally, the company would look only at cost, quality, and timing, but now it weighs each bid by the cost of carbon associated with a purchasing decision.

On this, some experts again expressed that demand will be key. When the users and buyers demand green energy, the supply chain will be more incentivized to become green. This is particularly relevant in China, where the expanding middle class wields substantial purchasing power and can demand a greener supply chain. In addition, some institutions are already in place to help finance the costs of greening the supply chain. However, challenges exist in monitoring an entire supply chain.

Technologies will be crucial in the corporations' ability to deliver on their climate pledges. The experts covered three specific technologies they believe are critical:

1. **Electrification**: The most important thing that can happen is the electrification of everything that can possibly be electrified, and we are making significant progress in this respect.
2. **Digitization**: Digitization will also be important, especially with respect to the developing area of the Artificial Intelligence of Things (AIoT), which is the combination of artificial intelligence (AI) and technologies with the Internet of Things (IoT). Digital technologies like blockchain can help us trace the source of hydrogen to ensure that the hydrogen we use is green.[22]
3. **Carbon capture, utilization, and storage**: Decarbonizing the grid will be accomplished via a combination of two processes: 1) using new energy resources like wind, hydro, and solar; and 2) maintaining traditional combustion energy resources while imposing carbon capture for combustion-style plants. For the decarbonization that we cannot innovate our way ***out*** of, we must innovate ***into*** things to remove carbon at a large scale, such as direct air capture.

Academia can play a very important role in partnering with companies to address the challenges of decarbonization. It is safe to say that academia is the source of much impactful new research – the mother of all innovation – before that innovation leaks out into the global economy. Peer-reviewed academic research tangibly addresses some very hard problems in materials science, chemistry, catalyst discovery, and carbon utilization and storage, among others.

Moving forward, the experts at the roundtable made the following suggestions.

- First, we need to find a **common definition of net-zero goals and establish regulatory standards** that will require unified disclosure practices for important information like the amount of carbon emitted.
- Second, we need to **transform the current carbon accounting scheme** to facilitate the decarbonization of the global supply chain. We need to move down to the granular, asset-level system for carbon accounting, though the logistical capacity required to implement that may not be readily available in the real world.
- Last but not least, we need **more legislation to encourage decarbonization, more quickly**. Common terminology and standards will provide a basis for carbon legislation.

22 Jones, J. S. (2021, February 4). *First blockchain platform for green hydrogen tracking developed*. Smart Energy International. Retrieved November 3, 2021, from https://www.smart-energy.com/regional-news/europe-uk/first-blockchain-platform-for-green-hydrogen-tracking-developed/.

Decarbonizing the Power Sector in the U.S. and China

To decarbonize the economy, the power, transportation, and industrial sectors stand out as the key sectors that warrant particular attention and exploration of collaboration opportunities. In 2019, these three sectors contributed the most to carbon dioxide emissions in both the U.S. and China (Figures 2 and 3). This section will focus on the power sector, followed by coverage of the transportation sector and the industrial sector, respectively, in the following two sections.

FIGURE 2. TOTAL U.S. GREENHOUSE GAS EMISSIONS BY SECTOR, 2019
SOURCE: US EPA

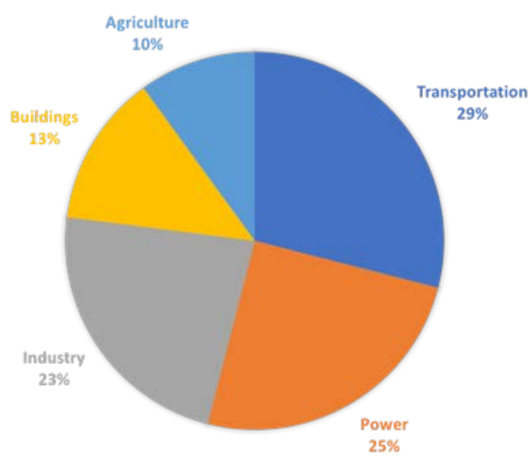
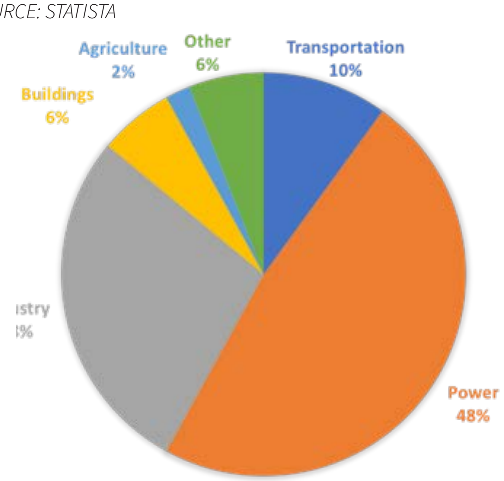


FIGURE 3. TOTAL CHINA CARBON DIOXIDE EMISSIONS BY SECTOR, 2019
SOURCE: STATISTA



The United States has set a goal to achieve 100 percent carbon pollution-free electricity by 2035. China has announced plans to "strictly limit the increase in coal consumption over the 14th Five-Year Plan period (2021-2025) and phase it down in the 15th Five-Year Plan period (2026-2030)."[23] These commitments are and will continue to drive new and more aggressive energy policies to decarbonize the electric grid in both countries.

The experts at the roundtable suggested focusing on the following areas on decarbonizing the power grid to deliver electricity safely and efficiently:

- Promote large-scale distributed generation of electricity based on renewables.
- Improve the predictability of renewable energy generation.
- Develop intelligent dispatch systems.
- Promote electrification and increase energy efficiency to improve demand-side response and promote multi-source coordination between electricity and heat sources.

When asked how to maintain reliability and resilience while decarbonizing the power sector, representatives from electricity and power institutes and companies highlighted the following insights:

- **The need for diversification**: Diversification involves thinking around multiple dimensions, including location, scale, time, speed, and the depth of decarbonization (i.e., what it takes to make decarbonization happen). Until we have the technology to address intermittency,

23 Reuters Staff (2021, April 22). *President Xi says China will start cutting coal consumption from 2026*. Reuters. Retrieved November 17, 2021, from https://www.reuters.com/world/china/chinas-xi-says-china-will-phase-down-coal-consumption-over-2026-2030-2021-04-22/.

diversification is necessary to balance reliability and resilience. On the bright side, advancements in a variety of carbon-neutral generation resources and energy carriers, such as green hydrogen and bioenergy, are paving the way to reliable and affordable 100-percent green electricity in the future.

- **The economics of the energy transition**: Decarbonization entails both negative and positive externalities. Investor-owned utilities in the U.S. reach decarbonization at different levels. To work towards cleaner energy in these utility companies, it is not unexpected that they would pass on high costs on end-use customers.

- **Communication**: How we talk about decarbonization in terms of speed and the impact of accelerated decarbonization is important. Decarbonizing faster than the system can handle can create unintended consequences, as witnessed in the large-scale power outages in parts of China and the United States. We should not over-promise what can be achieved over the short-term and be realistic about long-term goals. There are certain technologies that are necessary to make the transition as smooth as possible.

- **Capacity and the supply chain**: Capacity is needed to make things happen. Successful decarbonization requires a strong supply chain, which needs to be redesigned and globalized for resilience, not for the cheapest solution. On the supply side, it is more complicated than most people think – the market does not necessarily drive the supply chain. The supply chain involves national and global interests. This highlights the importance of cooperation between countries, especially between China and the U.S. If the supply chain cannot deliver enough, prices will increase. We should focus on the diversification of the supply side to deal with supply chain issues.

- **Understanding and deployment of carbon capture, utilization, and storage**: The importance of understanding and deploying CCUS cannot be discounted. That is going to be important in countries that have the geography to store carbon. We need policy to facilitate this. We need to understand more about the permitting process. CCUS can help us to continue using existing infrastructure that is needed to transition to zero-carbon by 2050.

- **Knowing counterparts**: bilateral collaboration is often difficult because we simply do not know who our counterparts are and whom we should talk to. Organizing future workshops by sector will prove fruitful.

- **Digitization**: We are faced with fragmented practices like rooftop photovoltaic (PV) generation, which are difficult to coordinate on a mass scale. Thus, we need digitization to achieve the energy transition. Specifically, we need IoT technology to connect users to provide effective adjustments with the supply side.

Overall, the most promising strategy can be simplified and characterized as “electrifying energy demand” while “decarbonizing the generation sources.” However, decarbonizing the sources of electricity generation will inadvertently introduce high volatility and steep ramps, which refers to when the system operator must bring on or shut down generation resources to meet an increasing or decreasing electricity demand quickly. The traditional Tesla-Edison paradigm was never designed to handle those volatility and steep ramps. The increasing penetration of distributed energy resources (DERs) at or near the edge of the grid enables customers to generate and store their own electrical power and inject them back onto the grid. Most of these devices will be digitally networked, thus enabling remote monitoring, control, and aggregation in unprecedented ways. Unfortunately, the Tesla- Edison grid assumed passive loads and was never designed for active DERs and controllable loads. The configuration of the grid needs to change as well.

Last but not least, experts warned of the hazards of moving too fast in decarbonizing the power sector, such as mass outages (similar to the one in Texas earlier this year and recently in China), price volatility, and a mismatch between supply and demand.

Decarbonizing the Transportation Sector in the U.S. and China

There has been a global effort to electrify transportation and localize infrastructure for EV development. However, the incentives for and the processes of EV manufacturing have differed greatly in China and the U.S. In the U.S., there has not been a massive amount of support, contrary to what many would believe. A DOE loan was used for the Tesla company's Model-S development, but the conditions were considered by some as too strict. Apart from that, EV companies could leverage the EV tax credit and trade emissions credits with other auto manufacturers. In China, by contrast, there are subsidies at each level: manufacturing, users, supply chain, among others. Although this may have led to the pushing through of risky technologies at the start -- where there were quality challenges and, in some instances, bad technology -- the subsidies helped signal demand. That proved quite beneficial for the supply chain and led to massive developments later. China has an integrated supply chain that the country invested in about ten years ahead of the U.S. and the E.U.

Comparatively, the processes have been slower in the U.S. than in China. In China, the Ministry of Industry and Information Technology (MIIT), which is a state agency under the State Council tasked with the regulation and development of China's industrial branches and information industry, ensures a minimum technical bar to be met to attain subsidies. That has created a level playing field. In contrast, in the U.S., the relationship approximates that between a banker and a user, which can slow down the process and add extra administrative costs.

What are the future opportunities for EV development? The experts shared the following insights.

- **EV taxis**: So far, the EV industry has largely targeted personal vehicles. While there will always be demand for personal vehicles, we also need to think about how much time vehicles are operated daily. Personal vehicles are only in use about 5 percent of the day. Taxis, however, are in use around 30-40 percent of the day. There is thus great potential there.

- **Bidirectional charging**: the vehicle-to-grid (V2G) technology allows energy storage in an EV's battery to be released back into the grid. V2G technology makes it possible for a two-way flow of electrical energy (i.e., bidirectional charging). EV batteries' energy storage capability can help solve the intermittency inherent in renewables like wind and solar. Charged EVs could thus function as a "backup generator" of sorts, helping maintain household power when renewable sources are temporarily unavailable

- **Storage potential of EVs on the road**: In large countries like China and the U.S., long distance journeys are often necessary for commercial and household automobile travel. However, the network of EV charging stations remains underdeveloped across each country and clustered in certain areas. For example, California has almost as many EV charging stations as 39 other states combined. Until this infrastructure is developed, increasing the EVs' storage capacity and distance capability per charge is essential to continued uptake.

- **Decarbonization of the trucking, aviation, and shipping sectors**: Decarbonization of the trucking sector is happening right now, but more can be done for sectors like aviation. Short routes could be electrified first; the long-haul flights could resort to biofuels or fuel cells.

U.S.-China cooperation in the EV industry will be beneficial for both sides because they have intertwined markets. For instance, Tesla is the largest passenger New Energy Vehicle (NEV) in China, and BYD, a Chinese manufacturing company, is the largest commercial supplier in California.

What are some challenges for EV development in both countries, and bilateral cooperation? The experts voiced the following concerns.

- **Infrastructure**: This is related to an earlier point on the need to improve storage potential of EVs on the road. Without dramatically increasing the total number and distribution of electric vehicle charging stations in both countries, consumers will be unable to fully substitute EVs for the convenience offered by quickly and easily refuelable gas-powered vehicles.

- **Pricing models and regulatory policies regarding distributed energy resources (DERs)**: EV is a type of DER. Unlike in countries like Australia where the electricity market is highly deregulated, the markets in the U.S. and China have made it difficult for DERs to participate, nor have they had a fair chance to be compensated properly. In September 2020, the U.S. Federal Energy Regulatory Commission (FERC) issued the landmark Order 2222, which opened up many wholesale electricity markets to DERs. Integration of DERs into the market can help reduce consumer costs and lower emissions by providing alternatives to older fossil fuel plants. However, implementation of the order has been spotty so far, as state-level operators need more time to ensure compliance with the Order's terms and fully engage with stakeholders. Further federal support, and clarification of the terms of existing deregulatory processes, can be beneficial.

- **Tariffs**: Since the days of the Trump administration's "trade war" with China, tariffs on imported Chinese electric vehicles have long been a contentious issue between the two countries. President Trump imposed a 25 percent tariff on imported Chinese electric vehicles as an attempt to preserve the competitiveness of American automobile firms versus China's heavily subsidized manufacturers. These tariffs remain in place as of this writing and are viewed by the experts at the roundtable as a barrier blocking bilateral cooperation.

While national action is certainly necessary, a centralized solution is unlikely to succeed on its own. It is important to recognize that on-the-ground implementation will be handled by subnational units, like cities, and by individual households. Comprehensive partnerships with these communities will thus be essential for such work to succeed.

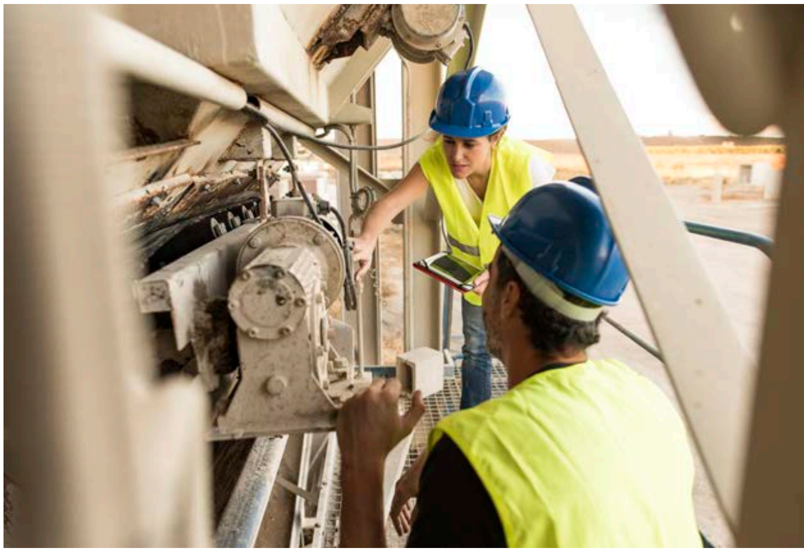
Decarbonizing the Industrial Sector in the U.S. and China

The industrial sector contributes about 28 percent of global greenhouse gas emissions, of which 90 percent are carbon dioxide emissions. Global efforts have contributed to innovation and the scaling up of decarbonization technologies for the power and transport sectors (e.g., solar PVs, EVs). However, less technological innovation and cost reduction progress has been made in decarbonizing the industrial sector. Improving efficiency in the production and manufacturing process will be crucial for decarbonization. Support from both central and local governments will also be critical.

Decarbonizing the steel sector in China will be critical because the country is the world's largest steel producer. China's steel contributes to 15 percent of the nation's total carbon emissions and over 60 percent of the global steel industry's carbon emissions. China is in the process of rolling out a plan for the steel industry to achieve peak emissions by 2025 and reduce emissions by 30 percent by 2030.

There is a lot of potential in greening the chemical manufacturing industry in the United States. Take the manufacturing of polymer products (e.g., rubbers, adhesives, coatings, synthetic plastics, fibers) as an example. Substantial energy goes into molding and casting procedures that use an old approach. In the case of plastic injection molding, a lot of energy is consumed to heat the plastic until it is liquified. New manufacturing processes use light in lieu of traditional energy.

In addition to steel and manufacturing, the cement industry is also a big contributor to industrial carbon emissions. Cemex, a leading multinational building materials company, recently declared a new ambition of reducing 35 percent of their net CO_2 emissions by 2030, and the company aspires to deliver net-zero CO_2 concrete globally by 2050. It is currently relying on proven technologies that have had very successful results. However, implementation and investment need to happen at a faster pace. The company plans to deploy new technologies post-2030.



Regarding improving efficiency in production processes, fluid handling is crucial but often overlooked. Fluid handling refers to the process where a flowing fluid is used for its mass and energy to facilitate processes and perform work, such as transferring heat, in the making of a product. We need to combine process improvements with close attention to pumping, air handling, and other fundamentals. Integrated design makes systems cheaper. "We bend minds, not pipes," as one expert put it. There are profitable ways to decarbonize the toughest sectors. Smarter structural design has the potential to profitably save half of global emissions produced from the steel and concrete industries.

In industrial decarbonization, a promising area is hydrogen production from solar energy. Ningxia Baofeng Energy Group, which had historically made coal-based chemical products, has set an excellent example. In April 2020, Baofeng started constructing the world's largest solar hydrogen project. The product is "green hydrogen" because, unlike traditional hydrogen production based on fossil energy, Baofeng uses solar electrolysis of water to produce hydrogen. The project is expected to reduce coal consumption by 254,000 tons and carbon dioxide emissions by 445,000 tons annually. Furthermore, and importantly, Baofeng aims to reduce costs from RMB 1.34/m^3 (about USD 2.33/kg) to RMB 0.7/m^3 (about USD 1.22/kg) or less.[24] If achieved soon, that will be sensational because the U.S. Department of Energy's Hydrogen Energy Earthshot (aka Hydrogen Shot), which was launched in June 2021 and aims to make clean and affordable hydrogen a reality, seeks to reduce the cost of green hydrogen to $1 per 1 kilogram in 1 decade (aka "111").

$$RMB\ 1.34/m^3 \times 11.126 m^3/kg \times 1\ USD/6.41\ RMB \approx USD\ 2.33/kg$$
$$RMB\ 0.7/m^3 \times 11.126 m^3/kg \times 1\ USD/6.41\ RMB \approx USD\ 1.22/kg$$

The experts at the roundtable warned that we need to think about unintended consequences and the circular economy from the onset. An example would be additive manufacturing. We need to get in front of the additive manufacturing revolution to think about business models so that we will not create unnecessary problems in the future. We must avoid the traditional linear economy with mixed waste streams and think about "made to be remade" business models.

24 国际能源网 (2021, April 22). 光伏制氢成本将降至7毛钱！宝丰能源为化工企业绿色转型打样！ Retrieved November 5, 2021, from https://www.in-en.com/article/html/energy-2303607.shtml.

AFTERWORD BY YI CUI, ZHIJUN JIN, AND JEAN OI

Yi Cui, Director of the Precourt Institute for Energy, Professor of Materials Science and Engineering, Senior Fellow at the Woods Institute for the Environment, and Professor, by courtesy, of Chemistry at Stanford University

Zhijun Jin, Dean of the Institute of Energy and Professor of the School of Geoscience at Peking University; Academician of the Chinese Academy of Sciences

Jean Oi, William Haas Professor of Chinese Politics, Senior Fellow at the Freeman Spogli Institute of International Studies, and Director of the Stanford China Program at Stanford University; Lee Shau Kee Director of the Stanford Center at Peking University

The United States and China are the world's largest two carbon-emitting nations and have the opportunity and responsibility to lead the world to combat climate change. In this series of roundtables, we focused on identifying opportunities and challenges in two realms: 1) accelerating decarbonization in the U.S. and China and 2) promoting bilateral collaboration on climate change.

We are encouraged by the high pace of change in technological innovation to date, especially in the two of the largest carbon-contributing sectors -- power and transportation. The industrial sector will follow suit and become the next frontier.

What worries us are the constraints that the tensions in U.S.-China relations have put on efforts to achieve our goals. A resounding takeaway from our roundtables is the need to keep fundamental research open and the critical role that universities can play regardless of U.S.-China relations. We need supportive policies and funding on both sides of the Pacific for more innovation to effectively deploy new technologies at large scale, to decarbonize faster. In the meantime, we need to remain cognizant of the need to build and maintain reliable and resilient energy systems.

Given that decarbonization must be a global goal, we also need to cooperate to devise politically and economically feasible ways to help developing countries move beyond fossil fuels to renewables. In all countries, diversification in energy resources, while developing greater storage capacity for renewables, is key to achieving the net-zero transition while minimizing unintended consequences.

We also need to understand that some obstacles to reaching decarbonization are not technical. We need to be clear who the key actors are and what incentives they face in both policymaking and implementation, especially during the transitional period when other goals, including meeting energy demands, seek priority.

We are greatly appreciative of having had the pleasure of gathering experts, practitioners, and leaders in the climate and energy field on both sides of the Pacific to learn from each other. As hubs of innovation, research, and the exchange of ideas, we believe universities have a leading role to play in encouraging the multi-disciplinary and multi-sectoral cooperation that will be crucial to address climate impacts in the coming years. Stanford University, with its various existing units and a new school on climate and sustainability, and the greater Silicon Valley ecosystem are poised to meaningfully contribute in this area. There is also motivation to establish a new center specifically tasked with facilitating exchange and collaboration with the Chinese side. We hope this series of roundtables will mark the beginning of many future bilateral collaborations, facilitated by universities, to blueprint needed solutions to help tackle energy, climate, and the transition to a net-zero world.

Meeting Participants

Drew Baglino - Senior Vice President, Powertrain and Energy Engineering, Tesla

Jeffrey Ball - Scholar in Residence, Steyer-Taylor Center for Energy Policy and Finance

Joe Bentley - Senior Vice President, Electric Engineering, Pacific Gas and Electric Company

Yang Cao - Vice President of Baker Hughes Company and President of Baker Hughes China

Steven Chu - Professor of Physics and Professor of Molecular & Cellular Physiology, Stanford University; 12th U.S. Secretary of Energy, 2009-2013

Will Chueh - Faculty Director, StorageX Initiative, Stanford University

Yi Cui - Director, Precourt Institute for Energy, Stanford University

Yanbao Dang - President and CEO, Baofeng Energy

Mincheng Ding - Managing Director, Envision Group

Daming Du - President, Huaneng Power International, Inc.

Chengyu Fu - Former Chairman, CNOOC and SINOPEC

Bin Guan - Managing Director, China International Capital Corporation

Wensheng Huang - Secretary to the Board of Directors, SINOPEC

Thomas Heller - Director, Sustainable Finance Institute, Stanford University

Maggie Jia - Chief Representative and Vice President, Cheniere Energy

Bing Jiang - President, Three Gorges Technology Corporation

Zhijun Jin - Director of Energy Institute, Peking University

Lawrence Jones - Vice President, International Programs, Edison Electric Institute

Lucas Joppa - Chief Environmental Officer, Microsoft

Junfeng Li - First Director and Academic Committee Director of China National Center for Climate Change Strategy and International Cooperation

Ting Li - Regional Managing Director, China Program, Rocky Mountain Institute

Xinchuang Li - Vice Chairman, China Iron and Steel Association

Yeqing Li - Chairman, Huaxin Cement Company

Xiaoshi Liu - Executive Deputy Secretary-General, China EV100

Yong Liu - Former Chief Economist, China Development Bank; Counselors' Office of the State Council

Priscilla Lu - Partner/Managing Director Sustainable Investments Group (Asia), Deutsche Investment Management Americas, Inc.

Amory Lovins - Adjunct Professor of Civil & Environmental Engineering, Stanford University

Matthew Margulies - Vice President of China Operations, U.S.-China Business Council

Arun Majumdar - Professor of Mechanical Engineering and Photon Science, Stanford University; Founding Director, ARPA-E, 2009-2012.

Dewen Mei - General Manager, Beijing Climate Exchange

Liang Min - Managing Director, Bits & Watts Initiative, Stanford University

Jean Oi - Founding Director, Stanford Center at Peking University, Professor of Chinese Politics, Stanford University

Lynn Orr - Professor in Petroleum Engineering, Emeritus, Stanford University; U.S. Under Secretary for Science and Energy, 2014-2017

Jiahua Pan - Fellow, Chinese Academy Social Sciences

Condoleezza Rice - Director, Hoover Institution; 66th U.S. Secretary of State, 2005-2009

David Sandalow - Inaugural Fellow, Center on Global Energy Policy, Columbia University

Vincent Saiso - Global Head of Sustainability, CEMEX

Alex Wang - Professor of Law, UCLA School of Law

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Yin Wu - Former Deputy Director, National Energy Administration

Neil Wilmhurst - Senior Vice President of Energy System Resources, Electric Power Research Institute

Fuqiang Yang - Peking University Institute of Energy, Former President, Energy Foundation China

Lei Yang - Deputy Director, Peking University Institute of Energy

Daojiong Zha - Professor of International Political Economy, Peking University

Lizi Zhang - Professor, North China Electric Power University

Yongwei Zhang - Secretary-General and Chief Expert, China EV100

Xiaoqiang Zhang - Permanent Vice-Chairman and Chief Executive Office, China Center for International Economic Exchange

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Peng Zhao - President and CEO, China Electric Power Research Institute

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