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Hearing on “China’s Energy Plans and Practices”

1 Executive Summary

On the road to becoming the world’s largest clean energy consumer, China has embraced a range of policies, including both demand-pull and supply-push, to shape energy markets. Resulting integration challenges such as high levels of curtailment are a symptom of both technical and institutional barriers, and will be attenuated in China’s long-term path to carbon neutrality. Energy policy priorities for China include energy security, affordability, industrial structure, air pollution, and climate change, which can be misaligned in the short- and long-term. The 2021 power shortages have revealed some interesting political discourse surrounding these various objectives, which have at least for now bolstered market reforms.

Recommendations for this Commission and for Congress:
1. Enhance visibility into and understanding of China’s energy sector challenges
2. Support China’s energy sector transitions through select clean energy cooperation
3. Study the dependence of the U.S. clean energy transition on developments in China

2 China’s Clean Energy Status and Policy Evolution

China is the world’s largest investor and consumer of clean energy, defined as renewable energy, civil nuclear energy, and generation with carbon capture and sequestration (CCS) for the purposes of this testimony. In 2021, 33% of China’s electricity generation (greater than 2,700 gigawatt-hours, GWh) came from clean energy. Completed investments in clean energy totaled 486 billion RMB (US$77 bn), 88% of annual investment in electricity generation. Wind and solar are the fastest growing clean energy sources, adding 100 GW of new capacity in 2021.[1]

Across all energy carriers, non-fossil sources accounted for only 15% of primary energy in 2020.[2] Roughly half of China’s coal, for example, is used outside of the electricity and heating sectors, primarily in industry where cost-effective clean energy substitutes are not widely available.[3] The majority of this testimony will focus on the electricity sector, because long-term energy system evolution trends predict large rates of electrification in other sectors (industry, transportation, household).

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[1] CEC, “2021 Electric Power Industry Statistics.”
[2] China’s methodology for calculating primary energy differs from international conventions and those used by the U.S. Energy Information Administration. See: Lewis et al., “Understanding China’s Non–Fossil Energy Targets.”
[3] Davidson, “From Barrier to Bridge: The Role of Coal in China’s Decarbonization.”

China's clean energy growth is the result of deliberate government policies to support technological development, manufacturing scale-up, and deployment. The Renewable Energy Law in 2005 set the foundation for the deployment of wind and solar by establishing connection rules and the mechanisms for fixed feed-in-tariffs (FIT) for onshore wind (2009), solar photovoltaic (2011), and offshore wind (2014). FITs provide a guaranteed stream of revenues, which in China are paid in two parts: the grid company (or direct consumers) pay up to the benchmark coal tariff and the central government pays the difference out of a central fund of renewable energy surcharges on electricity consumption. China also offers a value-added tax (VAT) reduction for renewable energy projects.

Drawing on earlier international business relationships, China's domestic wind energy equipment manufacturing sector developed quickly following strong demand-pull policies of the FIT and complementary policies.[4] By contrast, the domestic solar energy manufacturing sector was built first on export-led demand, and later supported by robust domestic deployment. Both sectors were facilitated by bottom-up manufacturing policy support of local governments.[5]

As costs of wind and solar equipment have fallen, China phased out the FIT for new onshore wind and solar as of 2021, forcing project developers to take the coal benchmark tariff or sign competitive market-based contracts. A complementary set of renewable portfolio standards (RPS) will create requirements at the provincial level to procure wind and solar, and incipient green electricity trading pilots could generate more revenue streams for projects.

Hydropower and nuclear energy tariffs have historically been determined on a project-by-project basis based on standards of cost-recovery. China has a long history of both small run-of-river and large reservoir hydro, and a mature planning process for large hydropower development. National five-year-plans typically establish lists of major hydropower projects and early-stage assessment priorities by river system.

China's civil nuclear energy fleet contains designs from France, U.S., Russia, and Canada, as well as indigenous development. Central government ambitions for nuclear energy were somewhat reduced following the Fukushima disaster, after which China slowed down new project development, conducted safety tests, and added additional safety measures to existing plants.[6] Nevertheless, China has the largest pipeline of active nuclear development domestically and has begun exports as well, supported by export credit.

Carbon capture and sequestration (CCS) is widely assumed in long-term energy growth models for China and many other countries, yet commercially operational CCS projects are still only at small scales globally. China has a few companies in oil & gas, power generation and industry exploring pilots. State-owned China Energy Investment Corporation completed a small test run of a post-combustion capture retrofit on a coal-fired power plant, which could be a model for future development.[7] CCS has been given a jolt following China's carbon neutrality

[4] Lewis, *Green Innovation in China*.
[5] Nahm, "Exploiting the Implementation Gap."
[6] World Nuclear Association, "Nuclear Power in China."
[7] Global CCS Institute, "Global Status of CCS 2021."

commitment, with the 14th Five-Year Plan and subsequent documents indicating an expansion of demonstrations and technological development.[8]

3 Development and Integration Challenges of Clean Energy

Variable renewable energies such as wind and solar have faced several barriers in the Chinese energy sector, stemming from institutional structures and unique technical characteristics. Three prominent barriers have been grid connection delays, subsidy delays, and curtailment.

First, wind and solar plants can be built quickly—in less than a year—which can create bottlenecks if grid connections do not keep pace. At one point, as much as 34% of China's wind generating capacity was built but not yet connected to the grid.[9] Causes for this delay include overzealous local government permitting and reticent grid companies.

Second, subsidies to cover the gap between the FIT and coal benchmark tariffs have also been extremely delayed. Causes for the delay reflect mostly a yawning deficit in the central fund that administers the subsidies based on surcharges on electricity consumers. Central officials have been unwilling to raise the consumer surcharge, which was a major factor leading to the end of the FIT program.

Third, intermittency of wind and solar creates challenges for the grid to balance supply and demand. If a renewable energy plant's output is not accepted up to its full availability, the foregone output is referred to as curtailment, and is in essence wasted free energy. Curtailment rates in China reached very high levels in 2016 when 17% of wind and 10% of solar was curtailed, and have since fallen. Causes of curtailment include technical factors such as insufficient transmission capacity or demand, as well as institutional factors such as inter-provincial trade barriers and insufficient incentives for flexible supply and demand.[10]

Technical and institutional challenges in expanding clean energy to achieve carbon neutrality will be even more acute than recent difficulties. By 2060, China will likely need between 2,000-3,000 GW each of wind and solar capacity, a ten-fold increase over today. At these levels, China will face extreme technical challenges to keep curtailment levels low, accommodate the large land use footprints of the deployment scale, and develop complementary infrastructure such as storage and transmission.

Curtailment levels under increasing penetrations of wind and solar will be driven largely by the flexibility of conventional generators to change output as needed and of demand to respond to changing grid conditions. China's massive coal fleet will likely continue to be repurposed via flexibility retrofits to form a "bridge" to a low-carbon energy system, rather than relying on large-scale replacement of coal with more flexible natural gas.[11] Demand response is primarily

[8] Hwabao Securities, "Carbon Capture Utilization and Storage Technologies: The 'Last Mile' of the Road to Zero Carbon."
[9] Lu et al., "Challenges Faced by China Compared with the US in Developing Wind Power."
[10] Davidson, Kahrl, and Karplus, "Towards a Political Economy Framework for Wind Power: Does China Break the Mould?"
[11] Davidson, "From Barrier to Bridge: The Role of Coal in China's Decarbonization."

deployed currently via time-of-use (TOU) rates for commercial and industrial customers that increase the cost of electricity during peak evening hours after the sun has set. Chinese localities will likely expand use of TOU rates—including by increasing the ratio between peak and valley pricing—as well as efforts to include demand in real-time energy markets.

Land use concerns have been largely muted in China's wind and solar buildouts to today as the most productive resources are located in the west and north where population density is lower. However, in increasing deployment by an order of magnitude, more facilities will need to be built nearby coastal demand centers where land is at a premium. Conflicts with agriculture, in particular, are likely to push some solar into smaller-scale distributed projects at factories and buildings, and could incentivize more creative multiple use arrangements for land.

China has the world's largest ultra-high voltage (UHV) transmission network, but this will need to expand still to accommodate large-scale balancing of clean energy sources. Transmission siting and permitting are relatively streamlined in China due to the scope of the country's two large grid companies as well as little public participation in the planning process. Many more high-capacity transmission corridors will need to be built, which could surface siting conflicts not present today. Battery storage projects will also need to be built at unprecedented levels.

Institutionally, China will likely continue to rely upon trusted methods of command-and-control targets and bureaucratic incentives to expand clean energy, while slowly embracing more market mechanisms. Targets laid out in planning documents and used in determining promotions are key levers to influence the behavior of government officials and state-owned enterprise (SOE) managers. These are a key fixture of China's energy and climate policy implementation and will continue to play a central role.[12]

Many of the above challenges, however, raise the costs of even minor inefficiencies induced by rigid planning measures. As a necessary means of cost control, China has been embracing more market-based mechanisms in recent years. In 2021, 45% of all electricity in China was sold via markets, up from just a few percent at the beginning of the current reform round in 2015.[13] Power sector reforms face substantial barriers from incumbent actors unwilling to give up generous central planning benefits, opportunistic local governments designing markets to favor certain interest groups, and central officials hesitant of provoking electricity price increases.[14] Current market designs are mostly in the form of medium to long-term contracts, which do not address the flexibility challenges of intermittent renewable energy and could, in fact, make integration worse.[15]

Last year, China also launched its national CO2 emissions trading scheme (ETS), which encapsulates the power sector at first, accounting for around 4.5 billion tons of CO2, and is targeted to expand to include up to 8 billion tons, or 70% of annual emissions. Due to the unique performance benchmark system, China's ETS does not create the same set of incentives as a normal cap-and-trade, and therefore, prices coming out of the market should not be directly

[12] Davidson et al., "Policies and Institutions to Support Carbon Neutrality in China by 2060."
[13] CEC, "National Electricity Market Transactions in 2021."
[14] Guo et al., "Power Market Reform in China."
[15] Davidson and Pérez-Arriaga, "Avoiding Pitfalls in Reforming China's Electricity Sector."

compared with EU's ETS.[16] In addition, the market provides limited fuel switching benefits, as renewable energy does not participate directly. It is better to think of the ETS as a means to accelerate the divergence between inefficient and efficient coal-fired power, begun under energy efficient dispatch and continued in electricity markets. In the long-run, the ETS can help build capacity for measuring, reporting and verification of emissions, and when combined with steady improvements in electricity markets could become a meaningful component of China's long-term climate goals.[17]

4 Alignment of Climate and Energy Policy Priorities

Climate change concerns are being added to a list of other energy policy priorities of China's central state, which include energy security, affordability, industrial structure, and air pollution. Reducing greenhouse gas (GHG) emissions may or may not align with these other goals, and the timeframe over which misalignment may occur varies. I will discuss a few examples.

First, deploying clean energy and accelerating power market reforms are aligned with energy security and other priorities. Energy security, encompassing the ability to satisfy consumer demand for energy and enhancing self-sufficiency, is improved if China can reduce its reliance on imported fossil fuels, prices for fossil electricity pass through costs, and more clean energy is installed. In response to the power crisis in 2021, China relaxed some restrictions on electricity markets and reiterated the need for more clean energy.[18] The more pressing need for supply security now aligns with the original promise of market reforms to enhance affordability through efficient production.

Second, measures to address air pollution generally align with long-term climate goals (such as deploying clean energy and building transmission), though may have some short-term misalignment. For example, China has rapidly scaled up installation of end-of-pipe controls that use more energy and emit more carbon, the same trade-off that the U.S. and many other countries make. These efforts also demonstrate that air pollution concerns have been more prominent than climate to date in energy sector planning.

Third, there are many long-term misalignments between climate and other energy policy goals. The response to the power crisis also included expanded domestic coal production to alleviate shortages and some language recentering the role of coal in the energy system. Another major effort has been to replace low-efficiency industrial facilities with newer, high-efficiency plants. These have immediate benefits in terms of energy security, reducing emissions, and addressing overcapacity and the financial health of sectors, but in the long-run, these efforts will lock-in carbon-intensive processes.

Fourth, the desired industrial structure for the energy sector from the perspective of the central state promotes efficiency, reduces overcapacity, preserves local autonomy and sources of growth, and maintains the leading role for the state sector. In electricity, large state-owned

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[16] Goulder et al., "China's Unconventional Nationwide CO_2 Emissions Trading System."
[17] Davidson et al., "Policies and Institutions to Support Carbon Neutrality in China by 2060."
[18] Davidson, "China's Power Outage."

incumbents dominate and are increasing in strength. Many efforts to date indicate a desire for managed competition, such as in the Northwest region where the five largest SOEs have each been given a province where they should consolidate capacity. The private sector, which played an important role in the growth of the renewable energy sector, is retreating from generation due to policy uncertainty and other barriers to competition.

5 Policy Recommendations for Congress

1. Enhance visibility into and understanding of China's energy sector challenges

As multiple energy crises in recent years reveal, China's energy sector decision-making reverberates globally. In this context, it is critical for Congress to fund programs that enhance U.S.-based expertise of China's energy challenges, including programs like the Fulbright and through research funding for international initiatives at NSF, DOE, EPA and other agencies.

2. Support China's energy sector transitions through select clean energy cooperation

It is in the U.S. national interest to support China in its efforts to transition away from coal, scale up clean energy deployment, and reduce GHG emissions. The "U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s" agreed to last November lays out several potential areas of cooperation.[19] These include sharing lessons on policies to support the integration of intermittent renewable energy, encourage effective transmission system balancing, and deploy distributed generation. Congress should support efforts by the State Department, DOE and other agencies for policy dialogue.

Beyond policy sharing, there is still much value in scientific R&D cooperation in areas that are less risky politically and where mutual benefits are possible, particularly in emerging low-carbon technologies such as CCS.[20] No country has adequately funded demonstration projects for the scale of CCS potentially required by mid-century. By leveraging and coordinating resources from more governments and firms, Congress can help accelerate the learning process.

3. Study the dependence of the U.S. clean energy transition on developments in China

The primary contributors to the falling costs of low-carbon technologies in the U.S. over the last decade have been efficiencies created by economies of scale and globalized supply chains. Many policies introduced or proposed to expand low-carbon technology manufacturing and deployment in the U.S., including import tariffs and local content obligations, run counter to the very causes of historic declines. Congress should fund studies into the costs and benefits of integration with China on R&D and manufacturing of mature and emerging low-carbon technologies. Further analysis is also needed at the level of specific technology pathways into the economic and national security risks of various degrees of integration and of ongoing developments in China.

[19] https://www.state.gov/u-s-china-joint-glasgow-declaration-on-enhancing-climate-action-in-the-2020s/
[20] Karplus, Morgan, and Victor, "Finding Safe Zones for Science."

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