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CLEAN TECH INNOVATION IN CHINA AND ITS IMPACT ON THE GEOPOLITICS OF THE ENERGY TRANSITION

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The year 2020 not only brought a devastating global pandemic, but also tied with 2016 as the hottest year in recorded history (*Kann and Miller, 2020*) and saw record-breaking wildfires, flooding, droughts, and severe storms. COVID-19 and climate change together cost millions of lives and billions of dollars. The need for rapid and coordinated global action against these common dangers has never been more apparent. Climate change has also become a matter of national security, a threat multiplier that is increasing the risk of political instability, terrorism, mass migrations, and conflict over resources.

The window for effective global action is narrowing, requiring massive scale-up of existing clean technologies and breakthroughs in new ones at a pace never achieved before. Finding effective ways to cooperate in accelerating the battle against climate change is therefore of paramount importance to all nations, even as they compete for geopolitical advantage in the global energy transition.

Many governments, companies, and individuals have contributed to the unprecedented growth of renewable energy and other low-carbon technologies. China, despite its continued support for fossil fuels at home and abroad, has arguably done more to date than any other country to accelerate the diffusion of clean technologies. But much more needs to be done, and quickly, to reach the goals of the Paris Agreement and avoid the worst consequences of climate change. There is plenty of room for healthy competition, especially in developing the frontier technologies that are needed in hard-to-decarbonize sectors such as heavy industry and long-haul transportation.

China's impact on the global energy transition

Driven by economic, energy security, and air pollution concerns, as well as market opportunity, China has invested nearly $900 billion in renewable power and fuels since 2009, more than twice as much as the next largest investor, the United States (*Renewables 2020 Global Status Report, REN21*). It now has more than a third of global solar and wind installed capacity, and leads the world in bio-power, hydropower, solar water heating, and geothermal heat output (*Renewables 2020 Global Status Report, REN21*). The country controls over 60 per cent of global manufacturing in every step of the solar supply chain (*Bloomberg News, 14 September 2020*) and is home to five of the world's top 10 wind turbine manufacturers (*BloombergNEF, 18 February 2020*).

On the transportation side, China is home to half of all electric passenger vehicles (*Automotive World, 15 January 2021*), 98 per cent of electric buses (*Sustainable Bus, 19 May 2020*), and 99 per cent of electric two-wheelers (Rathi, 2019). It leads in electric vehicle charging infrastructure and high-speed rail. Chinese firms also dominate the lithium-ion battery supply chain, controlling 80 per cent of the world's raw material refining, 77 per cent of cell capacity, and 60 per cent of component manufacturing (*BloombergNEF, 3 December 2020*).

Several factors have contributed to China's clean-energy leadership, including long-term planning, targets, and mandates; policies, regulations, codes, and standards; financial incentives and market mechanisms; easy access to financing; public procurement and infrastructure development; and support for research and development (R&D), including applied research in manufacturing. Taken together, these measures constitute what scholars have termed China's 'energy technology innovation system', which is also part of the growing global system of energy technology innovation (*Gallagher, 2014*).

This system is largely responsible for China's ability to massively scale up its capacity to manufacture and deploy clean-energy technologies—although other factors, such as vast domestic markets and low labour costs (now of diminishing importance as automation takes hold), have also played important roles. The country's often-lax environmental regulations have made it easier to site renewable-energy facilities, build ultra-high-voltage transmission lines and high-speed rail infrastructure, and mine and process the critical minerals and metals that power current technologies. China has also protected its domestic industries against foreign competition through such means as local-content regulations, government procurement directives, and mandatory joint-venture requirements. Those measures are in many cases being eliminated as China's own industries grow.

In the beginning, China's clean-energy entrepreneurs often trained overseas and relied on partnerships with foreign firms to access new technologies, rather than their own R&D. Instead, they turned a razor-sharp focus on shaving production costs in order to stay competitive against domestic rivals. This led to a continuing series of cost-cutting innovations in the manufacturing process (*Helveston and Nahm, 2019*). These innovations have often been incremental. But given the scale of manufacturing, they have contributed more than any other factor to making clean technologies affordable, and increasingly competitive with fossil fuels, in every country.

Largely as a result of China's innovative manufacturing techniques, economies of scale, and integrated supply chains, solar photovoltaic (PV) module prices have dropped around 90 per cent in the last decade (*Roser, 2020*). The International Energy Agency has declared solar power to be the 'new king' of global electricity markets, the cheapest source of electricity in history (*Boyle, 2020*). Onshore wind turbine prices have declined by 55–60 per cent since 2010 (*IRENA, not dated*). It is now cheaper to build new wind or solar capacity than to continue to operate 60 per cent of existing coal plants (*Carbon Tracker, 12 March 2020*). In 2019, for the first time ever, the majority of the world's new power-generation capacity came from solar and wind (*Eckhouse, 2020*).

The price of lithium-ion battery packs has dropped 89 per cent in the last decade, now averaging $137 per kilowatt-hour (kWh) (*BloombergNEF, 16 December 2020*). For some Chinese electric buses, battery prices have been reported below $100/kWh, the tipping point at which electric vehicles become cost competitive with traditional internal combustion energy vehicles. This is the geopolitical energy transition in action.

China still lags behind many other countries in overall innovation, but it is catching up fast. It has climbed quickly up the Global Innovation Index and now ranks 14th, the only middle-income country in the top 30 (*Global Innovation Index 2020: Who Will Finance Innovation?*). Total Chinese spending on R&D rose 12.5 per cent in 2019 to $332 billion, second only to the United States, though it is still only 2.23 per cent of China's gross domestic product (*Gawora, 2020*). The China region is also home to five of the world's 10 largest climate tech hubs, attracting $20 billion in venture capital in 2019, second only to North America ($29 billion) (*The State of Climate Tech 2020*).

New climate commitments

In September 2020, China's President Xi Jingping made a startling commitment: that the country would peak its CO_2 emissions before 2030 and aim to reach carbon neutrality by 2060. At the international Climate Ambition Summit in December 2020, President Xi further committed to enhancing China's Paris commitments by:

- reducing carbon intensity by over 65 per cent by 2030 (compared to its initial Paris commitment of 60–65 per cent);
- increasing the share of non-fossil energy in China's energy mix to around 25 per cent by 2030 (compared to 20 per cent in its initial target); and
- expanding total installed capacity of wind and solar to 1,200 gigawatts (GW) by 2030 (no previous target) (*Schmidt et al, 2020*).

These new 2030 commitments are an important step forward, though research shows that the plunging cost of renewables makes much higher targets both achievable and cost-effective (*He et al., 2020*). The upcoming 14th five-year plan (2021–2025), which will be unveiled in March, with more detailed five-year plans for energy, power, renewables, and climate to follow, will show whether China is on track to achieving carbon neutrality by 2060 or leaving much of the heavy lifting to later years.

In the meantime, China is no longer content to rely primarily on scaling up clean technologies that have been developed abroad. It is also pursuing technological breakthroughs in potentially game-changing technologies that are essential in the battle against climate change. Other countries, however, have also thrown themselves into the clean-energy innovation race, determined not to cede leadership to China again.

The race is on

Four key areas of competitive innovation are solar power, offshore wind, batteries, and hydrogen.

Solar power

China is phasing out generous subsidies for solar PV and other renewables, favouring subsidy-free projects that can compete with coal power on price (*Gao, 2020*). In determining the eligibility of solar projects for remaining subsidies, the Ministry of Finance gives priority to ones that utilize advanced technologies under its Top Runner program (*Xiao, 2020*). To compete effectively, Chinese solar firms are therefore investing heavily, not only in massive capacity expansions, but also in advanced technology R&D.

One Chinese company, JinkoSolar, just announced two world-record breakthroughs in advanced TOPCon n-type solar technologies, one of the leading new technologies in crystalline silicon solar, which dominates the market today (*Taiyang News, 7 January 2021*). Chinese researchers have also made strides in developing perovskite solar cells, a highly promising alternative to crystalline silicon solar that, if commercialized, could transform the entire solar industry (*Moser, 2021*).

But they face stiff competition from other countries. Europe has united all the major institutions involved in solar research into the European Perovskite Initiative (*Bellini, 2019*). This collaborative platform will create and support joint research programs and develop a common roadmap for perovskite commercialization. In the United States, an omnibus spending bill recently approved billions of dollars for clean-energy innovation, including $1.5 billion to support new PV technologies and initiatives to expand solar manufacturing and recycling technologies (*Shieber, 2020*). The Biden administration is poised to do much more.

Offshore wind

The International Energy Agency forecasts that the market for offshore wind, what it calls the only variable-baseload power-generation technology, could increase 15-fold and become a $1 trillion industry by 2040 (*International Energy Agency, Offshore Wind Outlook 2019*). The agency calculates that the best offshore wind sites could supply more than the total amount of electricity consumed worldwide today (*Ambrose, 2019*). The cost of offshore wind power has fallen by 62 per cent since the 2015 Paris Agreement, making it competitive with fossil fuel electricity (*Gerdes, 2021*).

Europe is currently home to nearly 80 per cent of global offshore wind capacity, with ambitious plans to expand capacity (*Toulotte, 2020*). It also dominates offshore wind turbine manufacturing and technical innovation, including the development of floating offshore wind projects. But competition is growing. General Electric is testing a prototype offshore wind turbine, the Haliade-X, that is the largest and most powerful in the world to date (*Reed, 2021*). It has the potential to transform the offshore wind industry.

Offshore wind capacity is surging in China. The country now ranks third in installed capacity behind the UK and Germany, despite the fact that its technology is less advanced than in the West (*Global Offshore Wind Report, World Forum Offshore Wind, August 2020*). Companies are moving up the technology learning curve, however, and have begun to develop floating offshore wind demonstration projects.

Batteries

Batteries are widely considered an essential 'silver bullet' technology for decarbonizing the transport and electricity sectors. The market is expected to explode in the coming years, driven by ambitious government electric vehicle adoption targets, fossil fuel vehicle bans, and the demand for battery storage to integrate growing amounts of renewable energy into the grid.

China dominates the global market in the production of lithium-ion batteries, the leading battery technology today. It continues to invest heavily in R&D, including in alternative chemistries, in order to achieve further cost reductions and higher energy densities. For example, Contemporary Amperex Technology, the world's largest lithium-ion battery producer and a supplier to Tesla, is building a $450 million battery R&D centre at its headquarters in China (*Scott, 2020*). The company plans to hire thousands of workers to develop next-generation energy storage technologies, including lithium metal, solid-state, and sodium-ion batteries.

Europe is determined to catch up. European governments, manufacturers, development banks, and commercial lenders are investing an estimated €100 billion in battery supply chains (*Krukowska and Starn, 2019*). Seven EU member states have also joined forces to provide €3.2 billion for battery R&D across the continent (*Publicover, 2019*). In addition to supporting the development of advanced chemical materials, cell and module design, and system integration, the program will focus on reducing the environmental and social impacts of the battery supply chain through innovative battery designs, more sustainable raw material sourcing and processing practices, and stepped-up battery recycling efforts.

Over the longer term, analysts agree that the cost and characteristics of lithium-ion batteries, as well as resource constraints, make them less attractive for long-duration energy storage. There is growing interest in developing alternatives to lithium-ion batteries using materials such as zinc, vanadium, or sodium. In 2020, more than $500 million in venture capital was allocated to energy storage-related start-ups (*Wesoff, 2020*). The Biden climate plan calls for R&D to develop grid-scale storage technologies at one-tenth the cost of lithium-ion batteries (*The Biden Plan for a Clean Energy Revolution and Environmental Justice, 2021*).

China's upcoming 14th five-year plan will reportedly support energy storage R&D designed to overcome current technology-development bottlenecks and improve China's international competitiveness (*National Development and Reform Commission, People's Republic of China, Guiding Opinions on Expanding Investment in Strategic Emerging Industries, 25 September 2020*).

The focus will be on developing long-duration and high-efficiency energy storage technologies, decreasing prices, and increasing lifespans to 15–30 years. The plan will also promote modular, standardized, and intelligent technologies, second-life applications, whole life cycles, and sustainable critical technologies.

Hydrogen

'Green' hydrogen produced using renewable energy is a flexible and versatile breakthrough technology with the potential to play an enormously important role in reaching net-zero emissions. Although hydrogen could in theory replace virtually all fossil fuel use, its most promising applications to date are in decarbonizing heavy industry and long-distance transport.

China is the world's largest producer of hydrogen, but most of it is 'brown' or 'grey' hydrogen produced from fossil fuels and used as feedstock for ammonia plants (*Brasington, 2019*). Only three per cent is 'green' hydrogen (*Yue and Wang, 2020*). But this is starting to change, with a growing number of provinces and state-owned energy firms developing renewables-based hydrogen projects (*Yuki, 2020*).

China's current focus is on the commercialization of hydrogen-powered fuel cell vehicles, presumably in order to reduce its growing reliance on oil imports and capture the market for this emerging technology (*Electrive, 3 November 2020*). The central government has not yet developed a national strategy for green hydrogen development. But a national incentive program unveiled in September 2020, in which cities compete for RMB 1.7 billion in funding for fuel cell vehicle demonstration projects, gives extra credit to cities with the capability to provide low-carbon hydrogen (*Yuki,2020*). This signal has already triggered an increased interest in green hydrogen throughout the country.

In a bid to outcompete China, the EU has launched a €470 billion Hydrogen Strategy, designed to develop a world-class green hydrogen production and manufacturing industry (*Schubert and Haas, 2020*). The initial aim of the plan will be to develop cost-effective green hydrogen solutions for use in heavy industry. It aims to build 40 GW of capacity to produce hydrogen from renewable sources in this decade. President Biden's climate plan calls for using renewables to produce carbon-free hydrogen at the same cost as that from shale gas (*The Biden Plan for a Clean Energy Revolution and Environmental Justice*, 2021).

Conclusion

China has dominated the geopolitical energy transition to date with first-generation clean-energy technologies such as crystalline silicon solar, onshore wind, and lithium-ion batteries. Europe and the US are now racing to take the lead in developing next-generation technologies that promise improved performance and flexibility, innovative applications, reduced environmental and social impacts, and lower costs.

It is hard to predict who will win geopolitical advantage and market share in these emerging multibillion-dollar clean-energy businesses. But one thing is clear. Competition is essential in driving down the cost of green hydrogen and other breakthrough technologies to the point where they can compete with fossil fuels. Strategic collaboration in addressing major decarbonization challenges—such as how to reinvent cities, redesign industries, and minimize impacts on declining communities—is also vitally important (*Seven Challenges for Energy Transformation,* Rocky Mountain Institute, 2019). No country can succeed on its own in a fight for our future that we can't afford to lose.