WHITE PAPER

A Pivotal Moment for US Energy and Industrial Innovation

December 2024
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Over many decades, American industry has leveraged innovation and scale to gain competitive advantage in sector after sector. From breakthroughs in material and chemical sciences to advancements in component design, manufacturing processes, and digital technologies, US companies have used these two fundamentals—innovation and scale—to build leading positions and grow new global markets. It's a pretty simple equation: get the fundamentals right, set a vision for the future, and execute well on a level playing field.

Now the world is embarking on the broadest industrial transformation in 80 years, one that will reset the competitive positioning of companies, industries, and countries. This transformation will affect all of the materials, components, and technologies needed to expand and decarbonize global power systems, electrify transport and industry, ensure sustainable and healthy food systems, and supply the equipment for and construction of resilient infrastructures everywhere. That equates to between 30% and 40% of the world's projected new capital stock between now and 2050—by some estimates, $100 trillion and more.[1]

This "transition economy" presents an extraordinary opportunity to build long-term economic advantage. But as of now, the US is falling behind other countries in this race to the future—especially China. (While our focus here is on the US position, many of the issues we highlight also hold true for Europe—and in some ways the EU's challenges may be even greater, as they are compounded by the overall European competitiveness issues outlined in the Draghi report.)

In this paper, we look at the current state of the transition economy and the potential implications for the US if it fails to keep pace. And we show how, with thoughtful and bold action by policymakers and business leaders alike, the US can use innovation and scale to ensure its competitiveness in the decades to come.

The Current State of Play

Individual US companies both large and small have been highly successful in building competitive advantage in the fast-growing markets of the transition economy. One of the few obvious examples is Tesla, whose CEO, Elon Musk, has demonstrated the power of innovation and scale not only with electric vehicles but with batteries, space technologies, and energy systems; Tesla, founded in 2003, now accounts for more than half of the total market capitalization of global auto OEMs. Another example is First Solar, a renewable energy company specializing in cost-effective thin-film solar panels. Known for its American-designed and often American-made products, First Solar, founded in 1999, is one of the leading players in the utility-scale solar market.

Many other established US companies are placing strategic bets and building new businesses to succeed in the transition economy, with opportunities extending through entire value chains. Ohio-based Timken, for example, produces bearings for wind turbines and solar PV trackers and is seeing strong growth in its business. Timken is far from alone: a recent Harvard Business School study revealed that 45% of US industrial companies are selling solutions and technology for the transition economy. Even so, the US is lagging far behind other global players.

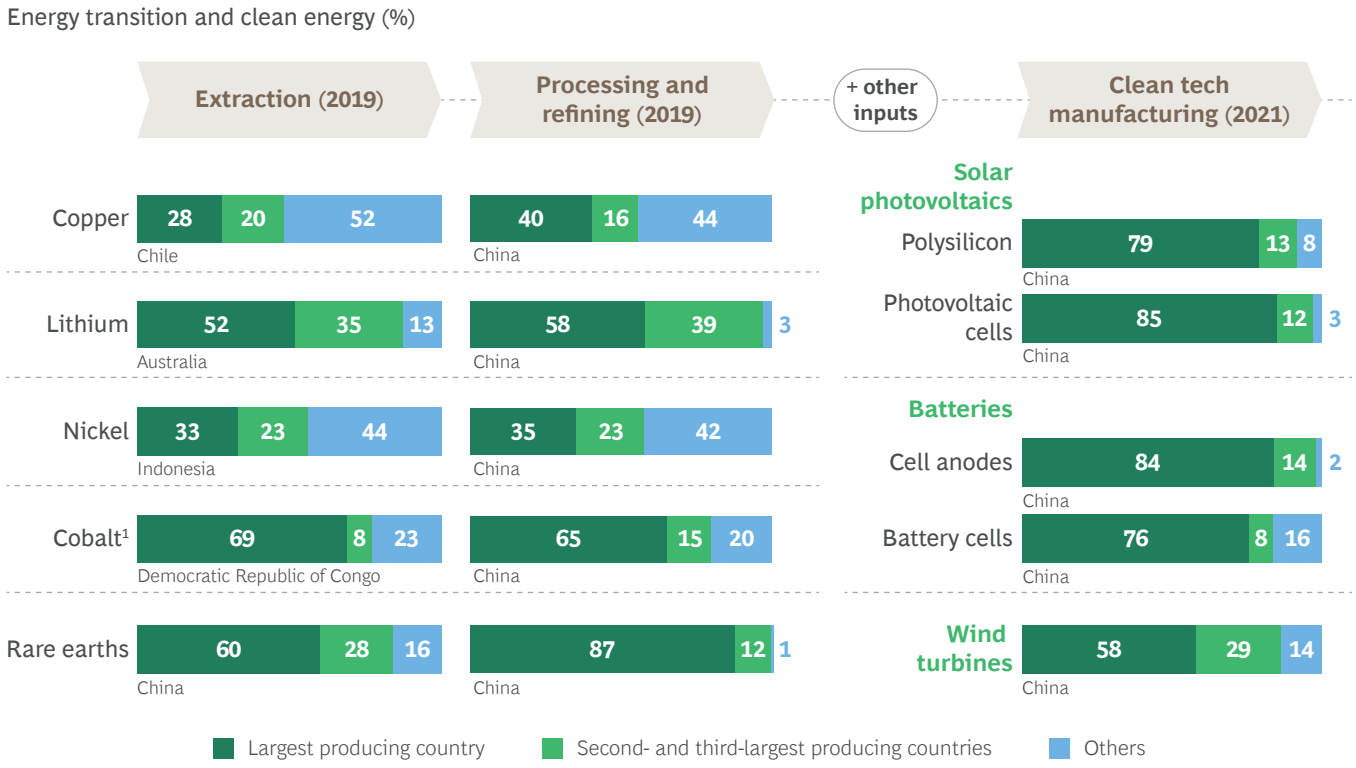
1. We have analyzed and quantified specific aspects of this transition in various reports in recent years, most notably in "How the US Can Win in Six Key Clean Technologies."

China Has a Huge Lead

China, the second largest economy by GDP, has emerged as a global leader in key transition-economy technologies, including onshore wind, solar photovoltaics (PV), batteries, and electric vehicles. This success reflects two decades of deliberate strategic effort on China's part, marked by substantial investments and policies that have driven innovation. This push resulted in a marked shift of Chinese exports from the "old economy" (manufacturing appliances, furniture, clothing) to the transition economy (EVs, lithium-ion batteries, solar PV).[2] It also triggered a dramatic, scale-driven decrease in costs for key transition-economy technologies such as solar PV and batteries, which now cost less than 10% of what they cost 15 years ago, according to the IEA.

Exhibit 1 below, adapted from the 2023 BCG report "A Blueprint for Energy Transition," illustrates the strength of China's current positioning with regard to entire value chains of key growth technologies and the lead it has built over the last decade:

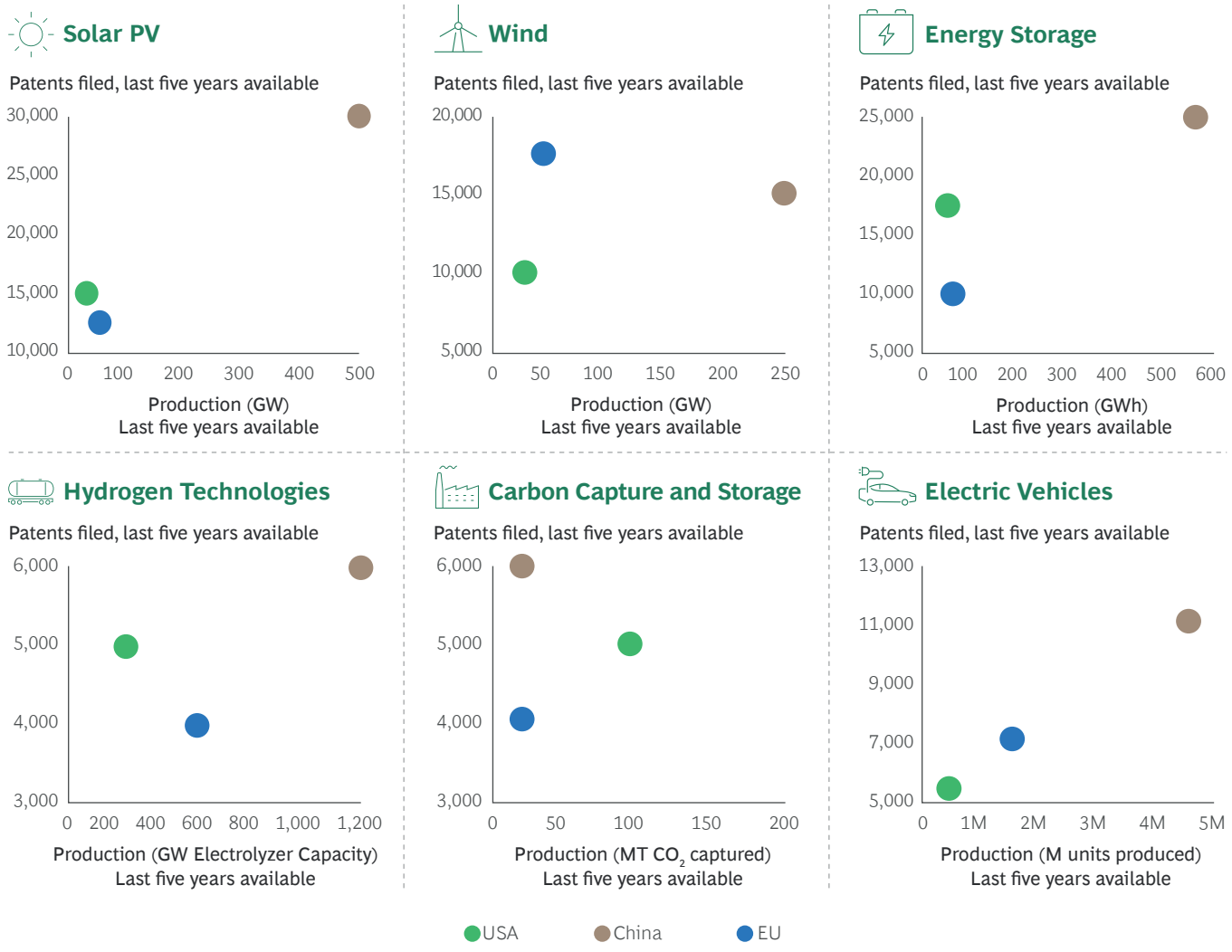
Exhibit 1 - The transition depends on concentrated value chains; more diversification could lower security-of-supply risks



2. Xiangrong Yu, "China Economics: Shifting Export Drivers: From 'Old Three' to 'New Three'," Citigroup, November 22, 2023.

To further capture this unfolding dynamic, consider our two criteria for future competitiveness: innovation and scale. In Exhibit 2, we examine the performance of China, the EU, and the US with respect to several transition-economy technologies. Performance is measured across two dimensions, with one axis representing strength in scale (expressed by a country or region's cumulative production advantage in a product or technology area) and the other axis representing strength in innovation and the creation of intellectual property (using as a proxy the numbers of new and cumulative active patents). Excelling in both dimensions fuels a cycle of increasing returns, driven by growing cost advantages and economies of scale, in turn enabling greater investment to extend one's lead in that technology.

Exhibit 2 - Innovation and scale determine future competitiveness on transition-economy technologies



Sources: Reports and publications from U.S. Energy Information Administration (EIA), European Commission, International Energy Agency (IEA), U.S. Department of Energy (DOE), European Wind Energy Association (EWEA), BloombergNEF, Benchmark Mineral Intelligence and many others.

While it is difficult to measure scale and innovation with precision, China's current advantage in terms of its future competitiveness is clear: it is outpacing the US and Europe in key transition-economy technologies such as electric grids, batteries and storage systems, electric vehicles, wind and solar energy, bioenergy, hydropower, catalyzers, hydrogen, CCUS, geothermal energy, and nuclear power.

The US Is Gaining Ground—but It's Still Behind

The US has begun to articulate elements of an industrial strategy that prioritizes innovation for the transition economy. Federal initiatives, such as the CHIPS and Science Act and IIJA (both bipartisan) as well as the IRA, allocate substantial funding to sectors like semiconductor production, energy generation and grids, heavy industry and manufacturing, artificial intelligence, and quantum computing.[3] These grants and policies are designed to bolster domestic capabilities, leverage scale through the US market, reduce reliance on foreign technologies, mitigate supply chain exposure, and ensure that the US remains at the forefront of technological advancement.

But even taken together, these efforts are likely insufficient to make the US a true leader in some of these industries. For some new energy technologies the window is rapidly closing; take lithium-ion batteries, for example, for which the market has commoditized and the US would likely operate at a cost disadvantage compared to the leading players. The US's best shot there might be to build a stronger position in the next storage-technology generation: solid-state batteries.[4]

At the same time, the economic benefits of the US participating in the transition economy are already apparent. Investments in transition-economy technologies, which are the best indicator for the future output and GDP contribution, have doubled from around 2.5% of total private investment in the US in 2020 to 5% in 2024 (including $71 billion alone in the third quarter of 2024), according to the Clean Investment Monitor. Employment in this sector of the US grew in 2023 with more than double the rate (4.9%) of job growth in the rest of the economy (2.0%) adding 149,000 new jobs, according to the Department of Energy.

Some might argue that many of these successes do not provide net economic benefits to the US because they involve subsidies—net job transfers from one part of the economy to another that are thus not necessarily long-lasting. For the US, the real prize would be truly competitive industries that do not rely on subsidies at all and that export their products and solutions globally. To achieve this goal, however, much bolder and visionary strategic initiatives are needed. It is important to separate this imperative from the political discussion around climate: this is about the ability of US companies to tap into increasingly sizeable value creation opportunities around the world—or not.

3. Rachel Snyderman, Jason Wiens, and Dane Stangler, "Innovation Nation: Toward a Comprehensive Approach to Boosting U.S. Economic Competitiveness," Bipartisan Policy Center, February 29, 2024.
4. The recent *Foreign Policy* article "How the United States Can Win the Battery Race" describes this in more detail.

Potential Implications of a Lack of US Competitiveness

Should the US fail to adequately capture the concrete and tangible opportunities related to the transition economy, the consequences could be significant—both in terms of missed economic opportunities and supply chain resilience issues.

Missed Economic Opportunities

The most direct consequence would be forgone economic growth and job creation in the coming decades as the world starts to move beyond fossil fuels. Capex-heavy, low-marginal-cost energy sources will supply 40% to 65% of global primary energy by 2050, according to the IEA—up from 10% today. The required investments in power generation and the energy system are gigantic and global. Most of the demand growth will happen in markets outside of the US; for example, over the next decade, India electricity demand is expected to increase by 100 to 150 terawatt hours each year, with investments in energy technologies, grid infrastructure and related products projected to be approximately $1.1 trillion to $1.4 trillion. Similar estimates for Latin America, Africa and Southeast Asia over the coming decade range from $700 billion to $900 billion, respectively[5].

This $3 trillion to $4 trillion market will be served by the globally leading suppliers of the relevant technologies. If the US is not one of those suppliers, millions of jobs in US communities could fall away—or not materialize at all. While it's difficult to accurately quantify the potential economic effects, assuming a "fair share" for the US of 20% to 25% of the global market for transition-economy technologies, the overall US shortfall could easily amount to $600 billion to $1 trillion over the next ten years.[6]

A more indirect effect of neglecting technologies central to the transition economy is harder to quantify but will likely be important. Already today, renewable power-generation technologies, especially solar PV, are less expensive forms of electricity, even with fully loaded costs. Costs are expected to decline further, paving the way to energy abundance with near-zero marginal costs. This might result in higher sustained electricity costs for domestic US consumers and industries compared to markets with a high penetration of renewables. In addition to that, energy abundance also opens the door to the electrification of many if not most industrial processes. While this will take time, innovation, early trials, scaling and first-of-a-kinds (FOAKs) are critical in the coming years to establish a leading position.[7] Not participating in these developments will create a vicious cycle that damages US competitiveness further and increases the gap between countries enjoying energy abundance versus those that don't.

The US will need to consider how its portfolio of globally competitive exports should shift as the world's economy transitions. Falling further behind on new energy technologies and related infrastructure could limit the US's ability to contribute to and benefit from the growing global demand for advanced energy solutions. This may also create challenges in maintaining a balanced trade portfolio when it comes to mineral fuels. At the same time, US exports today are instructive for how to build globally competitive and value-creating industries by harnessing innovation and scale and hold a lesson for the future. In 2024, the top five US export categories are all directly or indirectly related to hydrocarbons: crude oil, civilian aircraft (including engines and parts), refined petroleum oil, petroleum gases, and cars (most of which have combustion engines). The US is the world's largest oil and gas producer, and today a net exporter in stark contrast to its import dependence in the 20th century, thanks to its 21st century shale revolution, in which private and public investments in next-generation drilling technologies built a formidable US competitive edge, based on innovation and scale. Now is the moment to decisively do the same with transition economy industries to replicate the success for the coming decades.

5. For details on projected energy investments by region, see the "IEA World Energy Investment 2024" report and "IEA World Energy outlook 2024."
6. See also RMI's analysis in "X-Change: The Race to the Top," March 2024.
7. Michael Kearney and Lisa Hansmann, "From Constraint to Abundance: Charting an Innovation Agenda for the Energy Transition," Engine Ventures, 2024.

By contrast, by failing to capitalize on the global transition economy, there is a risk for the US of an increasing trade imbalance. To avoid that, and to maximize the net benefit in the next decade, it will be key for the US to build export excellence, including a suitable trade regime, so that it can serve the growing global demand for the technologies needed in transition economy. Just as importantly, this would reduce US exposure to export products which are likely to enter a phase of structural decline of demand.

Manufacturing and Supply-Chain Resilience Issues

In addition to economic competitiveness, limited penetration in growth markets, and global trade implications, the US must consider the issue of supply chain resilience, which is likely to become problematic if the US does not acquire a globally competitive position in the transition economy in the coming years. The resulting challenges are best described through the example of batteries, one of the critical technologies for a wide variety of mobile and stationary applications.

We've highlighted in the previous sections that the US, as of today, does not have the industrial supply chain required to produce and protect the batteries needed to power the transition economy, despite the large investments that have been announced recently. Accordingly, any disruption in trade flow—whether due to supply chain failures or geopolitical tensions—could affect value chains and impact prices. Look no further than new restrictions on the export of critical minerals, including graphite, from China to the US, which underline the sensitivity of the supply chain for batteries and semiconductors.[8]

Beyond the mere flow of materials, the concentration of battery technology expertise and production capacity outside of the US is likely to skew even further over the next few cycles of innovation. This could limit the US's ability to compete in emerging areas like energy-dense systems and grid-resilient energy supply and storage. Beyond immediate supply concerns, dependence on foreign battery components increases the risk of cybersecurity breaches and intellectual property theft. Ensuring a diversified and resilient supply chain—both domestically and through partnerships with global allies—will be critical for the US to remain a key contributor to (and beneficiary of) these emerging sectors.

In addition, there are second-order effects to be considered, given the criticality of batteries for many fast-growing applications that are increasingly important for power-grid resilience—long-duration storage, for example. Batteries are also emerging as important components in supplying power to data centers in a cost-effective and sustainable manner.

Recent US efforts to gain more control of critical supply chains for battery production, such as Li-Bridge, are a step in the right direction. But these efforts are likely not yet sufficient to improve the competitive positioning of the US in global battery supply chains.

How the US Can Remain Competitive

While the US is behind in the transition economy, the race is far from over. Most transition-economy technologies are still years away from their expected peak capacity. And the US and Europe are catching up: in 2022, China invested 26 times the amount on these technologies as the US and Europe combined, according to RMI, whereas by 2025 that multiple will have shrunk to a factor of 2.4[9].

To continue on that trajectory, and to strengthen its global competitiveness in the transition economy, the United States could pursue a strategy focusing on innovation and scale in the key technology areas where it has the best prospects for competing in the global marketplace. There are four key priorities that advance both US innovative capacity in these areas and build up market scale for US transition economy industries:

8. The implications are further analyzed in "What China's Critical Mineral Ban Means for the US," MIT Technology Review, December 2024.
9. See RMI's report 'The Race to the Top, March 2024.

1. **Build a strategic and integrated industrial policy for the transition economy.** The US can begin by aligning on critical transition technologies that it can profitably export or lead through US industry's manufacturing networks. National efforts of this scale have fared well in the past—think of the War Production Board, the Apollo program, the Interstate Highway System, or (more recently) Operation Warp Speed. Any such effort would need to be distinctly forward-looking, placing a premium on technologies in which the US can be a prominent and competitive innovator at home and abroad—for example, solid-state batteries, grid software, advanced geothermal systems, and clean data centers.

2. **Double down on RD&D.** As part of its industrial policy, the US can increase its investments in research, development, and demonstration in areas where it makes sense. The US has a fantastic legacy in RD&D, and it has the right talent and institutions to achieve breakthrough innovations time and again. True and lasting technological leadership needs to be built from the bottom up, and it will be critical to identify areas and (emerging) technologies where the US has a true structural advantage. This also implies "cutting the losses" in areas where the gap is too large or commoditization has already progressed very far—in solar PV, for example, and (probably) in lithium-ion batteries.

3. **Leverage the US market for innovation and scale.** The domestic market—with its scale and diversity—is a strategic asset which can be the launchpad for the US to win new international markets. Over the next decade, the rest of the world, excluding China, will require more than five times the new energy that the US will need. By initially stimulating and expanding demand for new energy technologies and infrastructure, the US can enable American companies to invest in innovation—moving up the experience curve and building production scale, training workers, and lowering their costs so they can lay the foundation to win globally and capture the tremendous future global growth. A thriving and leading private sector—supporting the diverse needs of entrepreneurs, investors, and innovation ecosystems—is the cornerstone of a winning industrial strategy. This can come in the form of incentives, financing, alignment of policies, regulatory simplification, standard setting, or other public goods.

4. **Foster the power of demand creation, domestically and internationally.** One of the most effective levers to scale up new technologies is to create actual demand in the marketplace, even if at initially small volumes. Public procurement can be a useful and relatively cost-efficient lever to create demand for emerging technologies; procurement is an area where billions of dollars (not hundreds of billions) can make a meaningful difference. Similarly, boosting exports through the Export-Import Bank of the United States and the US International Development Finance Corporation can have a similar effect. The US can leverage its global leadership position to become a trusted trade, investment, and technology partner in the transition economy. Emerging powers in the Global South, including countries such as Indonesia to Peru, are eager to grow and would benefit from foreign investment, the transfer of technology, and access to funding. While the focus of innovation could be in the US, homegrown technologies lend great potential to forge mutually beneficial alliances that in turn secure critical supplies (for example, critical minerals) and expand export markets for US manufacturers.

America's future standing as a leading industrial economy hinges on how effectively it innovates and scales the technologies needed to win in the coming decades. This will require an intentional industrial strategy aimed at advancing US leadership in critical areas of the transition economy. By fostering innovation, building resilient supply chains, and strengthening its manufacturing footprint, America can help power a sustainable and electrified world while contributing to shared global progress.

The authors would like to thank Nick Shariat, Leandro Urbano and Varun Sivaram for their thoughtful contributions.

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