

Powering Innovation: A Strategic Approach to America's Advanced Battery Technology

BY NADIA SCHADLOW, ARTHUR HERMAN, AND BRADY HELWIG

A REPORT OF THE HAMILTON COMMISSION ON SECURING AMERICA'S NATIONAL SECURITY INDUSTRIAL BASE



© 2021 Hudson Institute, Inc. All rights reserved.

ABOUT HUDSON INSTITUTE

Hudson Institute is a research organization promoting American leadership and global engagement for a secure, free, and prosperous future.

Founded in 1961 by strategist Herman Kahn, Hudson Institute challenges conventional thinking and helps manage strategic transitions to the future through interdisciplinary studies in defense, international relations, economics, health care, technology, culture, and law.

Hudson seeks to guide public policy makers and global leaders in government and business through a vigorous program of publications, conferences, policy briefings and recommendations.

Visit www.hudson.org for more information.

Hudson Institute
1201 Pennsylvania Avenue, N.W.
Fourth Floor
Washington, D.C. 20004

+1.202.974.2400
info@hudson.org
www.hudson.org

Cover: An employee works on the production line of a lithium-ion battery factory on November 14, 2020 in Huaibei, Anhui Province of China. (Wan Shanchao/VCG via Getty Images)

Powering Innovation: A Strategic Approach to America's Advanced Battery Technology

BY NADIA SCHADLOW, ARTHUR HERMAN, AND BRADY HELWIG

A REPORT OF THE HAMILTON COMMISSION ON SECURING AMERICA'S NATIONAL SECURITY INDUSTRIAL BASE



ABOUT THE AUTHORS



Nadia Schadlow

Dr. Nadia Schadlow is a senior fellow at Hudson Institute and co-chair of the Hamilton Commission on Securing America's National Security Innovation Base.

Dr. Schadlow was most recently US deputy national security advisor for strategy. She served on the Defense Policy Board from 2006 to 2009 and is a full member of the Council on Foreign Relations. Her articles have appeared in *The Wall Street Journal*, *Foreign Affairs*, and several edited volumes. Dr. Schadlow holds a BA from Cornell University and MA and PhD from the John Hopkins Nitze School of Advanced International Studies.



Arthur Herman

Dr. Arthur Herman is a senior fellow, director of the Quantum Alliance Initiative, and co-chair of the Hamilton Commission on Securing America's National Security Innovation Base at Hudson Institute. His research programs analyze defense, energy, and technology issues.

Dr. Herman has authored ten books, including *Freedom's Forge: How American Business Produced Victory in World War II* and, most recently, *The Viking Heart: How Scandinavians Conquered the World*. He is a frequent contributor to *Commentary*, *National Review*, and *The Wall Street Journal*. Dr. Herman received his BA from the University of Minnesota and PhD from Johns Hopkins University.



Brady Helwig

Brady Helwig is a research associate at Hudson Institute, where he supports the work of senior fellow Nadia Schadlow and the Hamilton Commission on Securing America's National Security Innovation Base. A former Hudson intern, he has held fellowships with the Hertog Foundation and the Alexander Hamilton Society. His research focuses on grand strategy, the US-China relationship, and emerging technologies.

TABLE OF CONTENTS

About the Hamilton Commission on Securing America's National Security Industrial Base	7
Our Commissioners	9
Executive Summary	11
1. Introduction	13
Defining Advanced Batteries	14
2. Electric Vehicles, Batteries, and Strategic Competition	16
Energy and Geopolitics: The Case of China	17
EV Batteries, Economic Competitiveness, and National Power	18
3. Concepts and Capabilities: Batteries, DOD, and the Future of War	21
Operational Energy and DOD	22
Great Power Competition, Decentralized Operations, and Batteries	23
Batteries and the Unmanned Revolution	25
Batteries and the Battle for the Electromagnetic Spectrum	26
Batteries in Orbit	27
4. Understanding the Battery Supply Chain	29
Cobalt	30
Lithium	30
Other Materials	30
Cell Component Production	31
Battery Pack Assembly	32
Recycling	32
Final Assessment	33
5. Toward a Strategic Approach to Batteries	34
Evaluating the Biden Administration's Battery Blueprint	34
Strategic Objectives	36
Policy Recommendations	36
6. Conclusion	43
Endnotes	45

ABOUT THE HAMILTON COMMISSION ON SECURING AMERICA'S NATIONAL SECURITY INDUSTRIAL BASE

In 1791, Alexander Hamilton, America's first secretary of the Treasury, set out to make the United States "independent of foreign nations for military and other essential supplies." He also foresaw a critical role for government in encouraging "new inventions" in manufacturing through patent and trade policy, as well as through government support, since these innovations would be crucial to the new nation's security.

Today policymakers are once again considering how to reduce American vulnerabilities in strategic industries. Over the past two decades, the United States grew dependent upon other countries for the supplies of key components. These vulnerabilities became apparent during the COVID-19 pandemic, which laid bare US dependence on global supply chains across a range of strategic industries. America's competitors view this dependence as a potent source of geopolitical leverage. China

in particular has weaponized economic dependence in its drive for global preeminence. To reduce American vulnerabilities and boost innovation, the United States must bolster manufacturing capability and reshore supply chains in strategic industries.

Hudson Institute's Hamilton Commission on Securing America's National Security Innovation Base examines sectors critical to American national security and proposes policy recommendations to reduce dependence and advance US leadership in these industries. Members of the Commission include elected officials of both parties, national security experts, former government and military officials, scientists, engineers, and industry leaders. Supported by the latest Hudson Institute research, the Commission will identify the policy tools needed to reduce US vulnerabilities by building secure and resilient supply chains in strategic sectors.

OUR COMMISSIONERS

Bryan Clark is a senior fellow and director of the Center for Defense Concepts and Technology at Hudson Institute, where he leads studies there in naval operations and fleet architecture, electromagnetic warfare, autonomous systems, military competitions, 5G telecommunications, and command and control. He previously worked as a senior fellow at the Center for Strategic and Budgetary Assessments.

Dr. Thomas J. Duesterberg is a senior fellow at Hudson Institute. An expert on trade, manufacturing, economics, and foreign policy, Dr. Duesterberg conducts research on trade with Europe and China, reform of the World Trade Organization (WTO), global competition in advanced technologies such as 5G, and the strength of the US manufacturing sector.

US Congressman Mike Gallagher represents Wisconsin's 8th District in the US House of Representatives. He is a veteran of the United States Marine Corps. Following his military service, he worked as a staffer on the Senate Foreign Relations Committee. Rep. Gallagher currently serves as the co-chair of the Cyberspace Solarium Commission and on the House Armed Services and Transportation and Infrastructure Committees.

Dr. Sridhar Kota is the Herrick Professor of Engineering at the University of Michigan. He is the founding executive director of MFOresight: Alliance for Manufacturing Foresight, a federally funded national think-and-do tank focused on enhancing the US manufacturing innovation ecosystem. From 2009 to 2012, Dr. Kota served as the assistant director for Advanced Manufacturing at the White House Office of Science and Technology Policy.

Dr. Zara Larsen is a global industry operational executive and intrapreneur with diverse engineering, technology, and business systems integration know-how, know-what, and most important, know-who. While serving at the US Department of State into 2021, she was involved in interagency economic security strategy endeavors with US allies and partners to address geo-

political challenges in critical technology sectors, including 5G, semiconductors, energy, critical minerals, fintech, and supply chain continuity.

Sec. Ellen Lord served in the Department of Defense as the first undersecretary of defense for acquisition and sustainment. After leaving her DOD role, Sec. Lord established EML Enterprises, LLC, providing advisory services that leverage her industry and government experience. Prior to her government appointment, Sec. Lord was president and CEO of Textron Systems, where she led a broad range of products and services supporting defense, homeland security, aerospace, infrastructure protection, and customers around the world.

Dale Lumme is the national executive director of the American Society of Naval Engineers and has held a variety of executive leadership positions. After serving as a naval aviator for 25 years, he worked as the executive assistant to the Atlantic Fleet Commander and to the Chief of Naval Operations, and as the staff director to the Navy Office of Legislative Affairs, House of Representatives for the Secretary of the Navy.

US Congresswoman Stephanie Murphy represents Florida's 7th Congressional District in the US House of Representatives. She previously served as a national security specialist in the Office of the Secretary of Defense. She currently serves on the House Ways and Means Committee and the House Armed Services Committee, where she is vice chair of the Subcommittee on Intelligence and Special Operations and is a member of the Subcommittee on Tactical Air and Land Forces.

Scott N. Paul is president of the Alliance for American Manufacturing (AAM), a partnership established in 2007 by some of America's leading manufacturers and the United Steelworkers Union. He has written extensively about Alexander Hamilton's role in forming US national economic policy. Mr. Paul currently serves as the board chair of the National Skills Coalition and sits on the Leadership Council of the Alliance for Manufacturing Foresight.

Heather Penney is a senior resident fellow at the Mitchell Institute for Aerospace Studies, where she conducts research on defense policy with a focus on leveraging the advantages of aerospace power. Ms. Penney is a recognized expert on a broad range of defense policy issues, including future force design concepts, information and operational architectures, autonomy and unmanned systems, acquisition and the industrial base, and force structure considerations within the global security competition.

Chair Kimberly Reed was the first female chair of the Board of Directors, president, and CEO of the Export-Import Bank of the United States (EXIM) where she worked helping companies succeed in the competitive global marketplace. While chair of EXIM, she introduced the “Program on China and Transformational Exports” to bolster US business competitiveness, especially in innovative sectors such as 5G and renewable energy.

Dr. Willy Shih is the Robert and Jane Cizik Professor of Management Practice in Business Administration at the Harvard Business School in Boston, Massachusetts. Dr. Shih’s expertise is in manufacturing, supply chains, and product development. His paper “Restoring American Competitiveness,” co-authored with Gary Pisano, won the 2009 McKinsey Award. His paper on the challenges of reshoring was featured in the Fall 2014 issue of the *Sloan Management Review*, and his Summer 2020 paper, “Is it Time to Rethink Global Supply Chains?”, was the most popular article of the year.

Pavneet Singh is a nonresident fellow at the Brookings Institution. His current work focuses on the nexus of emerging

technology, national security, and broader geopolitics. He is the co-author of the Department of Defense’s 2018 study on China’s technology transfer strategy, which was instrumental in the reform of CFIUS. Mr. Singh served in several roles on the National Security Council and National Economic Council in the Obama administration.

Dr. Anthony Vinci is a managing director at a private equity fund and an adjunct senior fellow with the Technology and National Security Program at the Center for a New American Security (CNAS), a fellow at the George Mason University National Security Institute (NSI), and a member of the Board of Trustees Technology Committee of MITRE. He previously served as the chief technology officer and associate director for capabilities at the National Geospatial-Intelligence Agency.

Lieutenant General Eric Wesley (Ret.) currently serves as the executive vice president of Flyer Defense, LLC. He most recently served as the deputy commanding general of Army Futures Command and the director of the Futures and Concepts Center. In this capacity, he oversaw the signature document defining US Army operations in the future, “The US Army in Multi-Domain Operations 2028.”

Michael Wessel is president of The Wessel Group Incorporated, a public affairs consulting firm offering expertise in government, politics, and international affairs. Mr. Wessel is also an original member of the US-China Economic and Security Review Commission. He has worked in public policy for more than 40 years, serving on the staff of former House Democratic Leader Richard Gephardt for more than two decades.

This report reflects the views of the authors, but views expressed herein may not fully represent the opinions of members of the Hamilton Commission. It does not reflect views of the respective employers of commission members. The authors take full responsibility for any factual mistakes or errors.

EXECUTIVE SUMMARY

Changing consumer preferences and government policies point toward widespread future adoption of electric vehicles (EVs). Advanced lithium batteries are the primary power source for EVs. Unfortunately, China dominates today's battery supply chain, from the extraction and processing of critical minerals like lithium to the production, packaging, and recycling of battery cells. In today's era of great power competition, control of the supply chains for advanced technologies such as lithium batteries will have a direct impact on national power.

Advanced battery technology will go a long way toward determining economic leadership in the EV market. The automobile industry is one of America's largest manufacturing sectors and accounts for some 3% of US GDP. But EVs and advanced batteries also have important military applications. EVs will function as mobile energy nodes on the battlefield, providing power for unmanned systems, communication links, electromagnetic warfare systems and more. These capabilities will help the US military conduct more decentralized operations in contested regions.

Beijing long ago predicted the strategic shift from fossil fuels to renewable energy sources and, in response, has spent years tightening its grip on the supply chains for this critical technology. If the United States desires to grow its EV industry, and fully capitalize on the military capabilities that batteries offer, policymakers must develop a national battery strategy that:

- **Makes and encourages investments in mining, processing, battery production, and recycling.** Given the strategic importance of batteries and their inputs, government support is necessary to build a robust American battery industry. Policymakers should leverage diplomatic and economic tools to work with friendly countries to ensure a sustained source of critical minerals, plus offer incentives for domestic mining and processing firms, cathode and anode manufacturers, and battery producers.
- **Drives innovation in mineral substitutes, next-generation battery technologies, and manufacturing methods to minimize supply chain vulnerabilities and leapfrog Chinese suppliers.** The US must develop alternate battery chemistries to substitute for costly or scarce minerals, boost R&D for next-generation battery technologies, and increase funding for improved manufacturing techniques for lithium-ion batteries.
- **Uses DOD tools to strengthen the supply chain for military batteries, with a goal of putting new capabilities in the field.** DOD must employ its policy tools to secure the supply chain for military-grade batteries, which are built to more extreme specifications than commercial versions.
- **Invests in workforce development and talent programs across the supply chain.** The US should cultivate domestic battery talent by investing in educational opportunities, supplemented by foreign expertise where necessary.



1. INTRODUCTION

Changing consumer preferences and deliberate government policies point toward the widespread future adoption of electric vehicles (EVs).¹ These vehicles are powered by advanced lithium batteries, which make up 30% of the cost of an electric car.² As the EV market grows, demand for lithium-ion EV batteries will skyrocket: demand is expected to grow some 330% by 2025.³ Beyond commercial uses, batteries also offer a variety of emerging defense applications. The US military will require advanced batteries to conduct dispersed operations with increasing energy demands in regions such as the Indo-Pacific, while many next-generation defense technologies rely on batteries to operate.

As the global economy shifts toward EVs and renewable forms of energy, such as solar and wind, advanced batteries sit at the center of the emerging energy competition. Currently, the

People's Republic of China (PRC) dominates the whole supply chain for advanced batteries. The competition begins with critical minerals—including lithium, nickel, cobalt—which are vital inputs for a wide variety of renewable energy technologies, including lithium-ion battery components. Beijing has for years encouraged Chinese mining giants to control the production of critical minerals around the world, as well as the refining and processing of these resources. The PRC also dominates the battery assembly process: 181 of the world's planned or operational battery “megafactories” are or will be located in China, compared to just ten in the United States.⁴ Beijing even leads the world in lithium-ion battery recycling efforts.

Photo: Robotics arms install the front seats of a Tesla Model 3 at the Tesla factory in Fremont, California. (Mason Trinca for *The Washington Post* via Getty Images)

In an era of great power competition, control of advanced technologies—such as advanced batteries—and their critical inputs will have a direct impact on national power.

This study examines the race for advanced batteries and their critical components and frames the competition within a broader strategic context. It then traces the current battery supply chain, highlighting potential bottlenecks and areas where the United States lacks critical domestic production capacity. Finally, it offers a set of recommendations for reframing the American approach to the battery supply chain and formulating a four-part national strategy on battery development and production.

Without control of advanced battery and critical mineral supply chains, efforts to shift toward a greener economy will be held hostage by China, capping the economic competitiveness of American companies. Moreover, the US military's adoption of unmanned systems (and weapons systems that can counter them); its shift toward decentralized operational concepts, which enable operations far from American shores in contested environments; and the exponential increase in energy demand across the operational environment require more resilient battery supply chains.

Defining Advanced Batteries

As defined by the battery manufacturer Saft, a battery is “a pack of one or more cells, each of which has a positive electrode (the cathode), a negative electrode (the anode), a separator and an electrolyte,” with energy storage properties—power and energy density, and an ability to be discharged and recharged—that vary depending on the chemicals and materials used.⁵ Batteries come in all shapes and sizes, from the small cells that power your remote control or cell phone to the massive, warehouse-sized batteries used to store energy for the power grid. This paper will focus primarily on medium-sized batteries, roughly the size of those used to power EVs, as these batteries carry the most strategic value thanks to their military applications and their role as the power source for EVs.

Having first entered commercial use in 1991, lithium-ion batteries are the most widely used battery technology, powering everything from cell phones to EVs. In the 30 years since they entered the commercial market, lithium-ion batteries have grown significantly cheaper, safer, and more efficient. According to researchers at MIT, lithium-ion battery costs have fallen 97% since introduction.⁶ Of the battery technologies currently on the market, lithium-ion technology offers a number of clear advantages, including a high energy density, more efficient charging, and a longer life span.⁷ These batteries contain a lithium-based metal oxide as the cathode—for EVs, this tends to be Lithium Nickel Manganese Cobalt Oxide, or NMC—and, most often, a graphite anode. Unfortunately, many of the minerals found in today's cutting-edge lithium-ion batteries are prone to supply chain bottlenecks (see “Understanding the Battery Supply Chain,” below).

The battery landscape also features a wide variety of legacy and next-generation chemistries. The latter include lithium-sulfur, nickel-sodium, lithium-silicon, and a host of other options. Benchmark Mineral Intelligence, a battery and mineral market research firm, predicts that over the next ten to twenty years, battery chemistries will diversify based on their applications and price points.

One promising option is the solid-state battery, a potential candidate to supplant lithium-ion chemistries.⁸ Solid-state batteries feature a solid electrolyte in place of the liquid electrolyte found in lithium-ion batteries, and they usually contain a silicon or lithium metal anode, rather than a standard graphite-based anode. This arrangement boasts several advantages, including solid-state batteries that can achieve higher safety standards and a higher energy density than traditional lithium-ion batteries. Solid-state technology might also allow for a transition away from cobalt and nickel in the cathode⁹—two critical minerals that pose significant supply chain hurdles. Unfortunately, solid-state technology continues to be held back by technical problems and limited durability. US start-ups such as QuantumScape and Solid Power plan to unveil commercial offerings within the next few years,¹⁰ but it may take at least a decade before solid-state technology becomes competitive.

For the purposes of this paper, *advanced batteries* is defined as current and future lithium-ion batteries, as well as novel battery chemistries, such as solid-state, that might someday supplant

lithium-ion technology. Discussion will be limited to batteries capable of powering commercial or military vehicles, except where otherwise noted.



2. ELECTRIC VEHICLES, BATTERIES, AND STRATEGIC COMPETITION

To be strategically significant, an energy technology must have an impact on a country's national power. Past examples of energy revolutions with a strategic impact include the nineteenth century's turn toward steam power—which drove the Industrial Revolution, transformed land and sea transportation, and revolutionized the world's battle fleets—and the twentieth century's unleashing of fossil fuel energy, which turned a byproduct of geology into a major source of strategic competition.

From this perspective, lithium-ion batteries are strategically significant for three reasons.

First, the growing global demand for renewable energy sources has elevated the geopolitical importance of critical minerals—the key input for batteries, as well as other renewable energy

sources—to the level that oil and natural gas have enjoyed for the last forty years.

Second, in the twenty-first century, a country's level of technological advancement is proving to be the chief determinant of national power. Thanks to the growing importance of technology across most industries, countries that control the inputs for and production of critical “platform” technologies, like batteries and semiconductors, now enjoy boosted economic competitiveness in the global market, as well as significant geopolitical leverage.

Photo: Aerial view of the No.3 pegmatite mining pit that contains deposits of 84 mineral types at the Koktokay National Geopark on September 27, 2020 in Fuyun County, Xinjiang Uygur Autonomous Region of China. (Shen Longquan/VCG via Getty Images)

Third, advancements in batteries will be crucial in enabling the US military's shift toward a more decentralized, agile, and survivable force posture, especially its push to both incorporate and counter unmanned systems.

Energy and Geopolitics: The Case of China

Access to energy supplies has long been a critical factor in geopolitical calculations. By setting renewable energy and climate policy as a priority for his administration, President Joe Biden has chosen to embrace renewable sources of energy at the expense of US oil and natural gas production. Some energy policy experts have termed this shift “The Great Transition.”¹¹

President Biden's initiatives reflect a broader political trend: around the world, key stakeholders in government, industry, and academia have committed to a global transition toward renewable energy sources. At the G7 Summit in June, for instance, leaders from the world's seven largest democracies pledged to support the “green revolution” for renewable energy. The document included a commitment to “accelerate the transition away from new sales of diesel and petrol cars to promote the uptake of zero emission vehicles.”¹² The idea of an energy reset has also gained traction with investors and energy executives.¹³ Earlier this year, BP chief Bernard Looney announced that the British energy giant would “embrace [the] energy transition,” while Exxon Mobil CEO Darren Woods claimed his company would be “supportive” of the Biden administration's zero-emissions goals.¹⁴ More recently, representatives from ten of the world's largest oil companies met with the Biden administration's top climate official and expressed support for a carbon tax.¹⁵

A key challenge to implementing this energy transition—of which EVs are a key driver—is that China “stands to gain more strategic advantage” from this shift “than any other country,”¹⁶ as a result of Beijing's long-term, conscious planning. There are four main factors driving China's push for clean energy: energy security, environmental concerns, economic considerations,

and the Chinese Communist Party's (CCP) push for technological self-sufficiency.

First, though rich in minerals and coal, China depends heavily on oil and natural gas imports. In 2017, the PRC surpassed the United States as the world's top importer of oil, and, as of 2019, China was importing some three million barrels more per day than the United States.¹⁷ Beijing is also the world's largest buyer of Middle Eastern oil.¹⁸ This leaves China reliant on strategic maritime chokepoints, including the Strait of Hormuz and the Strait of Malacca, which could be disrupted or closed in the event of a conflict. In 2016, nearly 80% of Chinese oil imports passed through the Strait of Malacca, a waterway roughly a mile and a half wide at its narrowest point.¹⁹

Second, environmental concerns are also playing a part in driving the PRC's energy transition. This might seem paradoxical, given that China has built some 240 coal-fired power plants across its Belt Road Initiative to date, with at least 13 countries in the Belt seeing double-digit growth in CO2 emissions.²⁰ Despite Beijing's continued reliance on fossil fuels, the shift toward green energy seems to be gaining traction in China. Chinese media outlets claim that Xi Jinping's personal political slogan and environmental policy—“clear waters and green mountains” [绿水青山就是金山银山], which he coined as a provincial secretary in 2005—has supposedly pushed Chinese cities and villages toward protecting the environment.²¹ On a more pragmatic level, much of China's population lives in low-lying areas near the Pacific coast that could be prone to rising sea levels and extreme weather events. China's major rivers are fed by glaciers high in the Himalayas, which could be threatened by rising temperatures—meaning that the country may face a significant water shortage in the coming decades that could exacerbate political tensions.²²

Third, China has positioned itself to garner massive economic benefits from the energy transition. Consider the economic rewards Beijing can reap by being the world's solar panel and bat-

tery factory as policymakers around the world shift their countries toward green energy. China has spent years tightening its grip on the supply chains for emerging technologies, including by controlling the production and processing of critical minerals.

These efforts are especially visible in Chinese attempts to corner the rare earths market, a subset of critical minerals used in various green and digital technologies (including wind turbines and EV motors). In 1992, Chinese leader Deng Xiaoping quipped that “the Middle East has oil, [but] China has rare earths.” China first began exporting rare earth mineral concentrates in the 1970s, then, as technology progressed, began to work its way up the value chain and “by the 1990s, it began producing magnets, phosphors and polishing powders.”²³ By the early 2000s, the PRC had rapidly scaled its rare earths production and processing operations, and by 2010, it controlled some 95% of global rare earths production, though that percentage has since decreased as other countries have caught up.²⁴

Over the last decade or so, China has taken a similar strategic approach to the strategic minerals and resources that are essential to producing batteries for EVs (See “Understanding the Battery Supply Chain,” below).

Fourth, Beijing’s moves to dominate green tech reflect the CCP’s wholesale push toward technological self-sufficiency. For decades, China relied mainly on forced technology transfer and intellectual property theft to drive innovation. But Xi, following his predecessor Hu Jintao, has sought to move away from this model, arguing that China must become “the master of its own technologies.”²⁵ “It is hard for China at this stage of development to acquire crucial core technology from other countries,” he explained in 2015, “because Western countries believe that the master will starve if he passes on his knowledge to his apprentice. So we must focus on our own innovation.”²⁶ The CCP has recently doubled down on Xi’s vision of promoting “indigenous innovation” in “core technologies.”²⁷ China’s 14th Five-Year Plan includes \$1.4 trillion investment in R&D for strategic

sectors, including batteries and electric vehicles.²⁸ Beijing has also rolled out a new geo-economic policy, known as the “dual circulation policy,” that seeks to reinforce Chinese technological innovation and self-sufficiency by building robust, self-contained supply chains in strategic sectors.²⁹

EV Batteries, Economic Competitiveness, and National Power

China’s bid for centrality in core technology sectors threatens to impact the global economic competitiveness of American firms, but the growing importance of technology in today’s world means that economic competitiveness also has a geopolitical impact. In the twenty-first century, economic competitiveness in critical industries has emerged as a key factor in geopolitics. Countries that host the producers of “platform technologies” gain valuable leverage that can be converted to political benefit. To take one example, Taiwan is home to TSMC, the leading manufacturer of cutting-edge 5 nm semiconductors. Commentators have dubbed Taiwan’s semiconductor industry a “silicon shield,” in reference to the security benefits provided by TSMC’s position in the global semiconductor value chain.³⁰ This link between economic competitiveness and national power informs China’s approach to matters of political economy and industrial policy.

With EV sales projected to jump more than 1000% by 2030,³¹ advanced batteries are crucial to the future of the automobile industry. The auto industry is one of America’s largest manufacturing sectors, contributing some 3% to the total US GDP.³² Each year, the auto sector purchases hundreds of billions of dollars’ worth of US-produced raw materials, including rubber, steel, glass, and semiconductors.³³ According to the Center for Automotive Research, the industry “contributes to a net employment impact in the US economy of nearly 8 million jobs.”³⁴ A loss of US competitiveness in the auto industry as the world transitions toward EVs would deal a significant blow to the US economy.

Along with other sectors of the global economy, the auto industry is adapting to growing political pressures to promote clean

energy options and meet net zero emissions targets. In Europe, for example, the United Kingdom has set 2050 as its target date for net zero emissions; Germany aims for a 95% reduction of its greenhouse gas emissions by the same date.³⁵ To help accomplish this, the European Union plans to offer EV purchase subsidies to consumers while fining companies that do not meet their emissions standards. Other global blocs are following suit, with China extending its tax break policies on EVs to 2022 to stimulate investment through the pandemic.³⁶

Shifting government policies, combined with a growing consumer interest in EVs, are motivating major auto companies to tap into the EV market. In 2019, automakers pioneered 143 new EV models and are expected to develop as many as 450 before the end of 2022.³⁷ These numbers include manufacturers not typically associated with the EV market such as Volkswagen, Ford, and General Motors. GM CEO Mary Barra recently announced that her company would move toward an all-electric vehicle lineup by 2035.³⁸ A few smaller brands, including Bentley and Volvo, have promised to phase out gas-powered models as soon as 2030.³⁹ University of Michigan professor of public policy Barry Rabe, describing the reasons for new corporate entry into the EV market, said that most auto manufacturers are afraid of being left behind to make “nostalgic vehicles that are being regulated or priced out of existence.”⁴⁰ Compounding these shifts, the Biden administration has announced an executive order that “sets a new target of electric vehicles representing half of new vehicles sold in 2030.”⁴¹

The combined effects of consumer interests, political incentives, and corporate competition will steadily expand EV production worldwide. Deloitte’s 2030 forecast anticipates a total EV sales jump from 2.5 million in 2020 to 30.1 million vehicles in 2030. According to the forecast, China will occupy half of the global EV consumer market, Europe 27%, and the US 14%.⁴² Within these countries, 48% of new cars in China are projected to be electric, Europe’s EV market share would approach 42%, and the US will have 27%.⁴³

This explosive projected growth in the EV market will produce a corresponding need for batteries. Global EV lithium-ion cell manufacturing is expected to grow dramatically from 747 gigawatt-hours (GWh) in 2020 to 2,492 GWh in 2025.⁴⁴ **It is vitally important for US policymakers to prevent a new kind of energy dependence—a reliance on China for the batteries needed to power electric vehicles.**⁴⁵ Across the entire battery supply chain, China vastly outstrips the US and will continue to do so, barring a realignment of US public and private interests. Without such a shift, the CCP could exert significant economic pressure on the United States.

This possibility touches on a key feature of Chinese economic and grand strategy: the CCP views economics and technology in starkly zero-sum competitive terms, as a contest involving clear winners and losers, and it readily weaponizes economic dependence for political gain. As one observer has summarized, “China thinks that power is the arbiter of world affairs, and that technology is power.”⁴⁶ Beijing feels poised to come out on top in the twenty-first century, with the domination of advanced technologies as a crucial key to victory.

Under China’s state capitalist model, the CCP utilizes industrial planning to drive innovation, especially in strategic sectors. Electric vehicles, advanced batteries, and other renewable energy technologies have stood at the forefront of these efforts for over a decade.⁴⁷ In China’s 12th Five-Year Plan, for instance, CCP leaders singled out new energy vehicles and the “new energy industry” as two of seven “strategic emerging industries” that would receive additional support.⁴⁸ As scholar Willy Shih noted shortly after the release of the 12th Five-Year Plan, Beijing’s EV policies “are designed to help the country become the leading global supplier of electric vehicles and components.”⁴⁹ Because “China recognizes that they are not saddled with legacy infrastructure associated with the manufacture of gasoline powered vehicles,” he explained, Beijing has positioned itself to use China’s “large market to leapfrog to a position of global leadership in electric vehicles.”⁵⁰

China's efforts to gain a foothold in the EV market were broadened in 2015 when the CCP released its Made in China 2025 industrial plan. New electric vehicles (NEVs) and advanced energy technology, including batteries, were again singled out as one of ten strategic sectors and promised government support.⁵¹ Made in China 2025 also makes clear that establishing internationally recognized “national champion” companies in the automotive industry is a core goal of Beijing's EV policies. For years, China has sought to develop brand-name car companies to vie with American, European, and East Asian competitors, but to no avail. CCP leaders view the transition from internal combustion engine vehicles to NEVs as a strategic opportunity for Chinese automakers to break through this glass ceiling.⁵² Experts differ on whether China can realistically attain this goal on their desired timeline, but, so far, the country's blend of subsidies and regulatory incentives has proved effective in boosting sales, at least in the Chinese market. As of 2019, China accounted for roughly half of global EV sales.⁵³

Scheduled for release this year, China Standards 2035 is the successor plan to Made in China 2025. It calls for establishing Chinese control over technology standards—the international rules that govern tech interoperability between different countries and companies.⁵⁴ Beijing's efforts to control standards for the EV and energy sectors are already underway. Last year, for example, the China Electricity Council published a set of national standards for next-generation wireless EV charging.⁵⁵ Beijing then released an additional set of standards for electric cars, electric buses, and EV batteries which went into effect at the beginning of this year.⁵⁶ Shaping tech standards allows China

to write the rules for future technologies, easing its path to economic and technological dominance.

By announcing and implementing these plans, the CCP has made clear that it views economic development and industrial dominance as a central arm of its grand strategy. China's growing posture at the center of strategic industries and their supply chains grants Beijing significant geopolitical leverage, which it uses to coerce other powers and elicit support for its preferred policies.⁵⁷ According to the Australian Strategic Policy Institute, China has used “coercive diplomacy,” which often involves economic threats, some 150 times over the past 10 years.⁵⁸ One of the clearest examples has been China's willingness to weaponize rare earths production. In 2010, for instance, China cut off rare earth supplies to Japan for months amid an ongoing political dispute.⁵⁹ In 2019, Beijing issued veiled threats that it may cut off rare earths supplies to the United States if the Trump administration continued to clamp down on Chinese high technology.⁶⁰ These threats have grown even more acute under the Biden administration: in spring 2021, Beijing threatened again to cut off rare earths imports to the United States.⁶¹

China's willingness to leverage access to rare earths is part of the CCP's broader strategy, which involves exercising political, economic, or diplomatic coercion to pursue its policy objectives.⁶² The case of rare earths is just one example of the CCP's exercise of economic coercion to achieve its strategic goals. China's consolidation of the advanced battery supply chain grants the CCP ample leverage should it continue this strategy.



3. CONCEPTS AND CAPABILITIES: BATTERIES, DOD, AND THE FUTURE OF WAR

Beyond the importance of batteries for the auto industry and their role as a platform technology that contributes to national power, these devices are crucial to future US military efforts to fight wars and complete missions. Batteries power everything from unmanned systems to electromagnetic warfare systems.

When the 2018 National Defense Strategy labeled China and Russia strategic competitors, it signaled that the Department of Defense (DOD) must reorient itself for great power competition.⁶³ Advancements in energy storage, such as next-generation lithium batteries, will be key in this shift because they will help enable the US military to operate further from traditional logistics chains. Thus, advanced batteries will help DOD adopt

new operational concepts—such as the US Army’s Multi-Domain Operations and the US Marine Corps’ Expeditionary Advanced Base Operations—which will require US forces to operate in decentralized formations tailored for contested environments.

Today, DOD uses thousands of different types of batteries, from tiny wearable cells to huge batteries for energy storage.

Photo: A US soldier from the 1st Infantry Division prepares an RQ-11 Raven miniature unmanned aerial vehicle during a mission to search for weapons caches on April 10, 2009 in Nishagam, Afghanistan. (Liu Jin/ AFP via Getty Images)

Batteries and Energy Fungibility

Discussions of electrification for the Department of Defense often focus on cutting emissions and decreasing energy costs, but the battery power found in EVs and hybrid-electric platforms could offer other advantages on the battlefield. One advantage is the fungibility of the electrical energy stored in batteries. Energy is fungible if it is easy to exchange or convert into a different form. The energy stored by fossil fuels is not especially fungible, as it can be difficult to convert into other forms of energy. You can't power your laptop with gasoline.

Unlike military vehicles powered by a traditional internal combustion engine, EVs (or hybrids) can function as an energy-providing "platform" for other systems in the field. The electrical energy stored in batteries can power or recharge any number of systems, such as satellite communication terminals, soldier systems, high-performance edge computing for artificial intelligence, unmanned systems, and electromagnetic warfare systems (including both high-powered microwave weapons and directed energy weapons).

To summarize, battery-powered military EVs should be viewed as a mobile energy node that can distribute energy for use beyond the drive train.

In addition, batteries are needed to power next-generation weapons. These include unmanned vehicles and the systems used to counter them, especially electromagnetic warfare systems. Plus, since unmanned systems must emit to perform their function, electromagnetic warfare systems will increasingly be deployed on unmanned systems, which will depend on batteries for power. Furthermore, energy demands on the battlefield are increasing at an exponential rate, while fossil fuel optimization and delivery will only see marginal improvement. Electric energy provided by batteries, meanwhile, will enhance

the fungible distribution of power (see Batteries and Fungible Energy, inset). To realize these applications fully, the United States must secure the supply chain for military batteries—a project which will require time, funding, and persistence. The US military cannot be dependent on energy sources produced by a strategic rival.

Operational Energy and DOD

From powering bases to fueling weapons systems, energy plays a crucial role on the modern battlefield. DOD consumes more than 10 million gallons of fuel daily, plus some 30 terawatt-hours of electricity per year.⁶⁴ Unfortunately, this energy supply chain creates vulnerabilities for American forces operating in contested environments. As Air Force General Deputy Chief of Staff for Strategy, Integration and Requirements Lieutenant General S. Clinton Hinote has explained, "when we play our wargames, almost always, our opponents will target energy as a major source of vulnerability."⁶⁵

These vulnerabilities came to the fore more recently during the wars in Iraq and Afghanistan:

A 2009 report by the Army Environmental Policy Institute calculated that US forces sustained one casualty for every 24 fuel resupply convoys in Afghanistan, and one US casualty for every 39 fuel resupply convoys in Iraq. The report estimated that in 2007, there were 5,133 required fuel convoys for Iraq and 897 required fuel convoys for Afghanistan, or 170 US servicemembers killed or wounded in action securing fuel convoys in 2007 alone.⁶⁶

Meanwhile, at the height of these wars, DOD energy bills ran in excess of \$20 billion per year.⁶⁷ Congress, seeking to address the problem, instructed the Pentagon to form an "operational energy" office that would address how the US military consumed energy on the battlefield.⁶⁸ In 2011, DOD released its first Operational Energy Strategy.⁶⁹ According to Sharon Burke, the Pentagon's first assistant secretary of defense for opera-

tional energy plans and programs, a key concern was to reduce the DOD's energy bills.⁷⁰ The main consumers of the 2011 Operational Energy Strategy were senior leaders in Afghanistan: according to US Army estimates, fuel and water represented 70 to 80% of the supply chain during the conflict.⁷¹

Great Power Competition, Decentralized Operations, and Batteries

Over the past decade, policymakers in Washington have largely shifted their attention from the Middle East toward East Asia. Yet, though the geopolitical environment has changed, the energy supply chain remains a major source of vulnerability for the US military. Russia and China have adopted strategies that use long-range precision massed fires—launched from maneuverable or difficult to detect platforms, with significantly improved sensor-to-shooter accuracy—to cripple opponents from a distance. Russian forces were able to use this strategy effectively during their 2014 incursion into Ukraine, and Moscow would likely use a similar strategy in a conflict with US and NATO forces.⁷² China, meanwhile, has developed a similar concept called the anti-access/area denial (A2/AD) strategy, designed to inhibit adversaries from moving freely into and within a theater of operations.⁷³ This strategy combines the use of long-range anti-ship missiles with submarine attacks, air interdiction, and cyberattacks, thus putting the US Navy in a much more vulnerable position and reducing unfettered access for US maritime forces.

To make matters worse, unfavorable geography in the Pacific means that resupplying US forces during a conflict would be both complicated and dangerous. DOD officials sometimes refer to this challenge as the “tyranny of distance”: to resupply troops stationed at bases in the western Pacific, ships departing Naval Base San Diego—America's largest Pacific naval hub—must sail across the largest ocean in the world, a journey that can take several weeks. In an age of satellite imagery, ever-present sensors, and long-range missiles, this would be a risky proposition during wartime.

To solve these dilemmas, DOD strategists are developing operational concepts for completing missions in decentralized, more agile formations that can operate far from supply lines. Examples include the Marine Corps' Expeditionary Advanced Base Operations, the US Navy's Distributed Maritime Operations, and the US Army's Multi-Domain Operations.⁷⁴ Each of these concepts seeks to use small, forward-deployed, highly capable units that are spread out across a large area. The physics of “being there” is a crucial part of deterrence; indeed, it has only increased given improvements in weapon accuracy, range, and lethality.

For these concepts to succeed, however, DOD must transition toward energy sources which can operate independently of legacy energy supply chains. General David Berger, 38th Commandant of the Marine Corps, has called logistics and supply chain management “the hardest problem going forward” for defense planners. “Nobody has contested our supply lines in 70 years,” he added.⁷⁵ Given the importance of the energy supply chain and the vulnerabilities it poses, the development of decentralized energy storage, like batteries, is vital to the future of decentralized operations. Today's diesel-electric generators—which currently power many of DOD's systems that use electricity—require fuel that must be transported. Renewable sources, such as wind and solar, could generate power independent of these supply lines (see Power Generation and Distributed Operations, inset). And yet, harnessing renewable power and storing it for use in defense systems requires energy storage technology, like batteries. As one DOD official put it to us, “Batteries are the one thing that allows distributed operations to work, since we need the increased range of weapons without the traditional logistical tail.”⁷⁶

The Pentagon has not remained blind to the importance of batteries. Since the 1990s, the Defense Department has sought ways to keep its supply of batteries reliable and secure.⁷⁷ Since 2017, the Defense Logistics Agency has run a Battery Network R&D Program to oversee the transition from lead-acid to lithi-

um-ion batteries. It has also procured batteries with a total value of more than \$1.1 billion to support the military power source supply chain.⁷⁸ The Pentagon has also joined the Federal Consortium for Advanced Batteries, which brings together federal agencies that are interested in ensuring a domestic supply of lithium batteries.⁷⁹

Nonetheless, the Defense Department also needs to consider how battery innovation will create new capabilities that boost force projection and mobility—key objectives for making decentralized operations a reality. For instance, since batteries are quiet and lack the heat signature created by internal combustion engines, hybrid vehicles or EVs can operate in a “silent watch” mode, allowing them to evade detection in contested environments. Over time, these developments could alter the US Army’s force structure as it reorients for great power competition. “In 10 years, some of our brigade combat teams will be all-electric,” explains Donald Sando, deputy to the commanding general at the US Army’s Maneuver Center of Excellence. Sando envisions 75-ton vehicles powered by high-capacity batteries, with electric motors capable of being recharged by a 10-50 kw generator. “Does that mean in 10 years, the Abrams tank will be fully electric? No, we’re going to replace it” and other combat vehicles over time, initially with hybrid-electric technology, Sando added, noting that tens of thousands of vehicles in the Army’s fleet would be replaced rather than recapitalized.⁸⁰

Battery-powered EVs also carry utility as a mobile energy node. As noted above, batteries in these vehicles offer platforms that power other technologies in the field (see Batteries and Energy Fungibility, inset; and “Batteries and the Battle for the Electromagnetic Spectrum,” below). These include satellite-linked communications networks, electromagnetic warfare kits, and small unmanned systems. To take one example, the US Air Force’s High Energy Laser Weapon System, or HELWS, is a directed energy weapon powered by a lithium-ion battery and mounted on a hybrid-electric utility task vehicle.⁸¹

Energy Storage, Distributed Operations, and the Power Generation Challenge

Batteries are an energy storage technology—a medium to store power generated by other sources and move it another location. However, many of the challenges facing the energy supply chain involve power generation, or the process of generating electric power (which falls outside the scope of this study). As DOD shifts towards more decentralized operations, it must rely on a broad mix of decentralized energy sources, including wind, solar, and nuclear power generation.

Though the US military plans to deemphasize fossil fuels as an energy source, they will not be phased out: **diesel-electric generators** offer a cheap and reliable decentralized power source and will continue to remain relevant.

Wind and solar are two of the fastest growing renewable power sources. Though quiet and easily accessible, these sources are dependent on environmental conditions. DOD is also studying the use of **hydrogen fuel cells** and **biomass fuels**. In addition, the Pentagon is exploring mobile **nuclear reactors** as a power source, with the leading proposal known as Project Pele. This is not a new concept, as aircraft carriers and nuclear submarines are currently powered by nuclear reactors.

Going forward, batteries will play a crucial role in storing energy generated by various types of decentralized power sources. Because these sources will not always be co-located with US troops, energy storage is essential to realize their benefits.

Finally, mobile battery packs will allow the individual soldier to operate more independently, keeping him or her linked to the overall command network while conducting distributed opera-

tions. On an average mission today, the typical American soldier carries about seventy batteries weighing between fifteen and twenty-five pounds total—enough to power a soldier’s devices for a standard seventy-two-hour patrol.⁸² To improve mobility, the Army wants to extend these patrols to 144 hours.⁸³ Implementing the highly mobile, “decision-centric warfare” that DOD strategists envision requires lighter and more mobile advanced battery technology.

With these goals in mind, DOD awarded a contract in July 2021 to Enovix Corporation—an American battery manufacturer based in California—to demonstrate “safe and efficient advanced lithium-ion battery technology” that will be worn and carried as part of US Army soldier equipment. Enovix will partner with Inventus Power, a firm that specializes in the design and manufacture of lithium-ion battery packs, smart chargers, and efficient power supplies. Inventus estimates that the total US wearable military battery market has reached \$350 million per year.⁸⁴

Wearable battery packs are certainly a harbinger of the future of “distributed operations,” but additional roles, such as unmanned systems and next-generation weapons systems, exist for advanced batteries.

Batteries and the Unmanned Revolution

Beyond stealth and mobility benefits, batteries will play a significant role in powering unmanned systems, which are key to the future of warfare. Unmanned systems come at a fraction of the cost of manned ones, can perform more dangerous missions, and run a higher risk of destruction. Incorporating these systems is a top priority for US policymakers. According to Christopher O’Donnell, acting principal deputy assistant secretary of defense for acquisition, “the current administration is putting emphasis on autonomous and remotely crewed systems, or ARCS, as a cross-cutting enabler for all DOD missions.” The aim is to “accelerate the adoption of these capabilities across all the domains,” he added.⁸⁵

Unmanned systems can be powered by a number of different sources, depending on their size and mission requirements. Generally, smaller platforms are more likely to be battery powered, while larger systems are powered by fossil fuels, fuel cells, or hybrid-electric engines.

Electric unmanned aerial vehicles (UAVs) offer several advantages: they are capable of being charged almost anywhere, are relatively easy to transport, offer reduced noise and thermal signatures, and can easily be recharged by replacing the battery pack.⁸⁶ Yet current limitations in battery technology constrain endurance and range: typical battery-powered UAVs can fly for a maximum of ninety minutes before they need to be recharged.⁸⁷ Moreover, these drawbacks mean batteries alone cannot power medium or large systems, or those that must fly for long periods of time.

The Department of Defense separates unmanned aerial systems into five groups based on weight, altitude, and speed. Group I systems make up the smallest classification, and include vehicles weighing under twenty pounds that fly less than 1,200 feet above the ground.⁸⁸ Of the DOD classifications, Group I and Group II systems are the most likely to be powered by batteries. These systems are designed to be lightweight, stealthy, and portable, and are typically used to conduct intelligence, surveillance, and reconnaissance missions—the top combatant commander priority for unmanned systems.⁸⁹ Group I systems are most useful at the tactical level to provide information on enemy positions beyond line of sight. Some Group II and III systems perform similar functions, though these cannot be launched by hand and are more likely to be used for lethal missions. Groups IV and V systems include the US military’s largest and most well-known UAVs, including the MQ-1 Predator and the MQ-9 Reaper. Systems in groups IV and V tend to be powered by traditional internal combustion engines, but hybrid propulsion arrangements are also a future possibility.

Since the introduction of drones nearly two decades ago, batteries have been used mostly to power smaller UAVs. In 2005,

for instance, AeroVironment's RQ-11 Raven won the Army SUAV (small unmanned aerial vehicle) competition. The Raven is a hand-launched, fixed-wing reconnaissance drone that allows soldiers to gather intelligence on enemy positions beyond line of sight. It has become one of the most widely deployed UAVs in the world, and has been quickly adopted by the Marine Corps, Air Force, and Navy. The Raven is powered by a rechargeable lithium-ion battery that provides sixty to ninety minutes of flight time.

For larger unmanned systems, the US military has begun investigating hybrid propulsion systems. These systems use traditional jet fuel to turn an engine turbine, which then charges a battery.⁹⁰ Rolls Royce reports that such technology can be used to optimize performance at various stages in the flight path: "gas turbines could be designed for stable travel performance," but "batteries and electric drives could provide additional power for climbing."⁹¹ According to analyst Bryan Clark, hybrid arrangements could potentially power systems as large as the MQ-9 Reaper drone, as long as speed is not a priority.⁹² For the US Air Force, in particular, larger unmanned systems and electric vertical take-off and landing aircraft are key priorities, as evidenced by the recently unveiled Agility Prime acquisition program.⁹³

Ultimately, a shift toward unmanned systems powered by advanced batteries will require addressing the military's concerns about lithium-ion technologies. For years, the US Navy shied away from lithium-ion technology due to safety concerns (lithium-ion batteries can be prone to thermal overload, meaning they present a fire risk). In addition, though batteries have become much more powerful in recent years, they still offer a low energy density compared to traditional fossil fuels. This means that batteries must be recharged frequently, which requires a nearby ground station and accessible energy source. Due to these power constraints, batteries have also lagged as a power source for autonomous or AI-enabled platforms, which need extra energy to perform calculations and transmit data.

As a result, many American UAVs, for instance, are powered by hydrogen fuel cells or internal combustion engines. To unlock the stealth and mobility benefits that batteries provide, however, the US military must develop more powerful, longer-lasting batteries.

Batteries and the Battle for the Electromagnetic Spectrum

Batteries also help power next-generation weapons, including electromagnetic warfare systems (formerly called electronic warfare systems). First deployed during World War II, electromagnetic warfare systems weaponize the electromagnetic spectrum to disrupt communications, destroy enemy equipment, gather intelligence, or counter enemy attacks. These systems are designed to help militaries gain an advantage in an increasingly contested information environment. Over the last few decades, the proliferation of cheap sensors and digital communications has made the electromagnetic spectrum a much busier place. In the civilian world, the combination of cheap sensors and internet connectivity—with signals sent via 5G networks—has helped create the Internet of Things, opening the door to a host of commercial applications. In the military world, opposing forces take advantage of the electromagnetic spectrum to communicate, spy on potential adversaries, and detect enemy forces.

Dominating the electromagnetic spectrum is a priority for militaries around the world, including the US military. In 2018, the bipartisan and independent National Defense Strategy Commission labeled electronic warfare "critical in any future conflict," especially in great power contests against Russia or China.⁹⁴ According to the Congressional Research Service, DOD requested \$10.1 billion for electronic warfare systems in FY2019, \$10.2 billion in FY2020, and \$9.7 billion in FY2021. The Pentagon is projected to spend more than \$50 billion on electronic warfare over the next five years.⁹⁵

Electromagnetic warfare also includes directed-energy weapons. According to the Defense Department's Joint Publication 3-85,

directed energy is “an umbrella term covering technologies that produce a beam of concentrated electromagnetic energy or atomic or subatomic particles.”⁹⁶ DOD defines a directed-energy weapon as “a weapon or system that uses directed energy to incapacitate, damage, or destroy enemy equipment, facilities, and/or personnel.”⁹⁷ Directed-energy weapons come in two main forms: high-energy lasers and high-powered microwave weapons. Each is a cost-effective solution for countering unmanned systems: lasers disable or destroy individual targets via a single concentrated light beam, while microwave weapons can take on multiple enemies and will be used to counter drone swarms.⁹⁸ One industry expert noted that “in five years, any large base that needs to defend its assets will have laser weapons, regardless of service.”⁹⁹ Pentagon spending on directed energy doubled between FY2017 and FY2019, from \$535 million to \$1.1 billion.¹⁰⁰

Electromagnetic warfare systems are important to counter unmanned systems, which most modern militaries are in the process of adopting. Unmanned platforms are relatively cheaper than manned counterparts and can be deployed against targets in large numbers, making it costly and tactically challenging to defend against them with traditional precision-guided munitions. Electromagnetic warfare offers precise and inexpensive ways to disable or destroy unmanned systems, and they boast a track record of success in countering smaller systems like drones: analysts believe that a Marine Corps electromagnetic warfare system successfully downed an Iranian drone over the Persian Gulf in July 2019.¹⁰¹

Batteries are an important power source for these systems, especially those designed for use with smaller, stealthier platforms, but poor battery performance remains a hurdle to further deployment. Last year, for instance, a DOD report noted that the batteries housed in the US Army’s Stryker vehicles were insufficient to power some electromagnetic warfare systems, including the Tactical Electronic Warfare System (TEWS). A Stryker equipped with TEWS “could operate on battery power for 20 minutes before requiring the engine to run to recharge the

vehicle batteries,” the report noted.¹⁰² Likewise, before portable directed energy weapons can be usable in the field, batteries must become longer-lasting, more powerful, and easier to recharge. “The problem [with directed energy] is the battery right now,” explains Brigadier General Julian Alford, commander of the Marine Corps Warfighting Laboratory/Futures Directorate. “When the scientists figure out how to make the size, weight and power much smaller, that would be something we can use.”¹⁰³ Thus, future applications of electromagnetic warfare systems, especially those deployed on smaller platforms, will depend partially on battery innovation and procurement.

Batteries in Orbit

Battery advancements are also critical for satellite systems, which will play an important role in any future conflict. Satellites and other space-based assets allow the US military to communicate, as well as track and target enemy forces. Military leaders have stated clearly that satellites are central to the unfolding competition in space. “The threat is clear: we’re in an era of great power competition, and the next major conflict may be won or lost in space,” former acting defense secretary Patrick Shanahan has warned.¹⁰⁴

Since the early 2000s, satellite manufacturers have shifted toward lithium-ion batteries to power their systems. For larger satellites, these batteries can be massive: currently, the most hazardous space debris is discarded batteries left to explode in orbit. Earlier this year, for instance, the International Space Station jettisoned a 2.9-ton pallet of spent batteries.¹⁰⁵ Smaller and more efficient batteries mean less mass launched into orbit—in other words, less risk accrued in an already contested environment.

The US military’s shift toward distributed operations—coupled with operational and strategic demands for stealthier vehicles, survivable unmanned systems, electromagnetic warfare-enabled information dominance, and additional satellites—mean that DOD must prioritize continued development

and access to advanced batteries. In the end, however, relying on battery rather than fossil fuel energy will be less a wholesale transition or transformation than a migration, much as the adoption of unmanned systems has been. The Defense Department needs to oversee a process in which innovations can be integrated without major disruptions, but

it also needs to look beyond existing supply chains for advanced lithium-ion batteries, to new battery designs such as solid-state, and adopt a realistic timeline for developing scalable domestic sources to meet DOD's battery needs, including the ability to manufacture battery cells. The reasons will become apparent in the next section.



4. UNDERSTANDING THE BATTERY SUPPLY CHAIN

The United States controls only a tiny fraction of the advanced battery supply chain. China dominates much of the mining and processing of critical minerals as well as cell manufacturing and battery assembly. These bottlenecks grant Beijing significant strategic leverage: given the CCP's penchant for economic coercion, it is not difficult to imagine how China could weaponize the battery supply chain against the United States.

The battery supply chain begins with the production of critical minerals, such as lithium and cobalt. Key metals must be extracted from mines, then chemically processed and refined in special facilities. These refined minerals are then used to create battery cells. Once cells are produced, they are combined to form modules, which are then wrapped into battery packs—a

process that takes place in dedicated “megafactories.” The last stage of the battery supply chain, recycling, comes about during the end-of-life cycle.

Critical minerals make up between 50 and 70% of the cost of an EV battery.¹⁰⁶ Currently, the United States lacks the capability to produce and refine many of these minerals, while China remains the leading global producer. In 2018, the US Geological Survey released a list of thirty-five mineral commodities considered critical to the economic and natural security of the United States.

Photo: Workers assemble lithium battery products on the production line of an energy company on May 28, 2019 in Yichang, Hubei Province of China. (Zhang Guorong/Visual China Group via Getty Images)

That list includes most of the minerals considered critical to the production of lithium-ion batteries: cobalt, lithium, manganese, and graphite.¹⁰⁷

Cobalt

Under the CCP's "Go Out" investment strategy, China has sought to secure critical minerals from around the world for its rapidly growing EV industry.¹⁰⁸ This is evident in the global competition for cobalt production. Cobalt is one of the most potentially problematic inputs for lithium-ion batteries, as production is concentrated in politically unstable regions: almost 72% of the mined production of cobalt comes from the Democratic Republic of the Congo (DRC). This is problematic due to humanitarian concerns, as reports suggest that child labor is still used in some Congolese cobalt mines.¹⁰⁹ While very little cobalt mining occurs domestically in China, Chinese companies have acquired stakes in foreign mines, particularly in the DRC, as well as Papua New Guinea and Zambia. Eight of the fourteen largest cobalt mines in the Congo are now Chinese-owned, accounting for more than half of the country's output.¹¹⁰ Thanks to the equity positions Chinese companies have acquired in foreign mines, "Go Out" policy activities have reduced China's reliance on cobalt imports from 97% to 68%.¹¹¹

In addition to investing in the foreign mining of cobalt, China dominates the upstream processes of cobalt supply. Cobalt must be chemically processed and refined before it can be used to make batteries. In 2019, China accounted for 82% of the chemical processing and refining of cobalt supply.¹¹² Just three Chinese firms are responsible for 46% of the world's total output.¹¹³

Lithium

Lithium consumption for batteries has increased significantly in recent years, and as the world transitions toward EVs, demand for the mineral is expected to spike. A recent report from McKinsey & Company anticipates a 340% increase through 2050, with 79% of growth projected to come from battery demand.¹¹⁴ Today, most lithium mining is concentrated in Latin

America and Australia; however, Chinese companies acquired mining operations in these countries to the point where they control much of the supply. Chinese mining giant Tianqi Lithium, for instance, owns a 51% stake in the world's largest lithium reserve, Australia's Greenbushes mine.¹¹⁵ Ganfeng Lithium, another Chinese mining giant, completed a deal in 2019 to secure 50% of one of the world's largest high-grade reserves at Mt. Marion mine in Australia. As a result of these efforts, China now holds direct or indirect control over 70% of the global lithium supply.¹¹⁶ Once mined, lithium, like cobalt, must be processed and refined in specialized facilities. China is also the dominant player in this step, refining 59% of the world's lithium in 2019.¹¹⁷

The US has the potential to develop a lithium supply chain. One American company, Albemarle, is among the world's largest lithium companies and owns the only operational lithium mine in the United States. While sources of lithium are relatively abundant in North America—the US has the fourth-largest reserves in the world¹¹⁸—there are significant barriers for US companies associated with its extraction. Many of these challenges are environmental and political: in January 2021, for instance, a second domestic lithium mine site was approved by the Trump administration, but it has faced stiff resistance from organized camps of environmental protesters and activists.¹¹⁹ Another hurdle is the lithium refining process: processing facilities are not only expensive, but they are also extremely energy-intensive, making it difficult for US companies to set up domestic operations.

Other Materials

Other minerals necessary for lithium-ion EV batteries include graphite, manganese, and nickel. Graphite makes up the anode material in most lithium-ion batteries, but China dominates all aspects of this supply chain as well. Beijing controls about 65% of the world's natural graphite mining capacity.¹²⁰ Before graphite can be used in batteries, however, natural graphite must either be refined into spherical graphite, or the material

Supply vs. Demand-Side Approaches to Battery Policy

The federal government can encourage growth in the battery and EV markets through two types of tools: demand-side incentives, which seek to increase consumer demand for batteries; or supply-side incentives, which support producers in bolstering production across the battery supply chain.

The Biden administration's supply chain report on batteries calls for a mix of both, but its use of demand tools has attracted the most attention. In the American Jobs Plan, the administration advocates for consumer EV rebates to increase market demand by offsetting the higher cost of electric cars. By contrast, supply-side approaches focus on boosting battery production by employing federal loan guarantees, tax credits, or subsidies to reduce producer costs. Examples of supply-side EV policies include the 48C Clean Energy Manufacturing Tax Credit and fast-tracking permitting for lithium mining.

In the battery market, federal purchasing is dwarfed by commercial demand, meaning that government purchase commitments for military-grade batteries are insufficient. Unfortunately, demand incentives, especially EV rebates, have mixed backing politically. Few Republicans in Congress support them, so EV producers cannot rely on these rebates to drive growth. In addition, over the last few months, leading producers of EVs—including Ford, GM, and Stellantis—have pledged to move towards all-electric lineups, meaning that demand incentives targeted toward consumers may no longer be necessary.

must be produced synthetically. China produces 80% of the world's synthetic graphite and 100% of the world's spherical graphite.¹²¹ The United States imports the majority of its graphite from China.

The story is similar for manganese, also an important input for battery cells. While China has very little mined production of manganese—only around 7%—it controls 93% of the chemical refining process.¹²² The United States has not produced manganese ore domestically since 1970 and relies fully on imports.¹²³

Unlike manganese, nickel is mined and produced in the United States; however, imports still account for some 50% of total consumption.¹²⁴ Despite minimal mined production of nickel, China is still able to dominate the upstream global supply of the mineral, as 65% of nickel chemical processing and refining occurs in the country.¹²⁵

Cell Component Production

After these minerals have been mined, refined, and processed, they are used as inputs for the components of the battery cell: the cathode, anode, electrolyte, and separator. All of these major components have supply chains of their own, but as with raw materials, the production of these component parts is dominated almost entirely by China.

Most of the lithium, cobalt, and nickel found in lithium-ion batteries is used to produce the cathode, making this component the most expensive part of the battery. Indeed, cathode materials account for over half of the total cost of producing battery cells.¹²⁶ China holds sway over the majority of global cathode production, some 61% in 2019.¹²⁷

China also dominates the production of anode material, which is primarily graphite-based. As noted above, China remains the sole commercial-scale producer of spherical graphite used in lithium-ion battery anodes, and it also controls manufacturing for battery-grade synthetic graphite. China produced 86% of all anodes (natural and synthetic graphite).¹²⁸ China also dominates electrolyte production—Chinese companies accounted for close to 60% of production in 2015¹²⁹—while Japan controls separator supply.¹³⁰

Battery Pack Assembly

Once these components are manufactured, they are packed into battery cells. These cells are then combined into modules, which are wrapped into finished battery packs. This process takes place in dedicated battery “megafactories.” As noted above, the majority of these specialized facilities are located in China, while relatively few can be found in the United States. As of this year, there are some 181 megafactories in various stages of planning and construction around the world. Of these, 136 are or will be based in China, as opposed to 16 in continental Europe and only 10 in the US. In 2020, China accounted for 72.5% of the world’s total lithium-ion battery cell capacity, with Europe accounting for 5.4% and North America for 9.2%. These numbers are not expected to change significantly over the next decade: Benchmark Mineral Intelligence, a mineral supply chain intelligence firm, projects that by 2030, China will account for 66.9% of the world’s cell capacity; Europe, 16.7%; and North America, 11.9%.¹³¹ This reliance upon Chinese industry could create major headaches for US manufacturers.

This is particularly true of batteries procured by DOD. Suppliers are forced to rely on cells made overseas, especially in Asia. Battery contractors concentrate on meeting the very specific requirements of individual DOD systems, rather than making standard types of batteries that meet multiple needs. As a result, few incentives exist to scale production to attract larger manufacturers to the DOD market. Without reliable domestic sources for cells; without large-scale manufacturers able to provide batteries cost-efficiently; and without an EV market and a corresponding demand for lithium-ion batteries to make up the differences, the prospect for meeting DOD’s long-term battery needs safely and securely is uncertain, to say the least.

Recycling

Recycling is the final step in the lithium-ion battery supply chain process. Large percentages of the critical materials in batteries can be reused, which can help reduce costs for these expen-

sive components. In addition, because the United States figures very little in the production of the key minerals and components needed for EV battery production, recycling can play an important role in reshoring some of these crucial supply chains.

Unfortunately, as is the story with the rest of the supply chain, China dominates the EV battery recycling industry, while US recycling of lithium-ion batteries remains in its infancy. In 2018, it was estimated that, of the 98,000 tons of lithium-ion batteries reported to have been recycled, 67,000 tons were processed in China.¹³² Given China’s status as the world’s largest EV market, it comes as no surprise that Beijing has treated recycling as a strategic priority.

Lithium-ion battery recycling faces a number of issues in the United States, including materials collection, transportation challenges, and regulatory hurdles. There is presently no national strategy for the mass collection and recycling of lithium-ion battery waste, as can be found in Europe and China. The removal of batteries from EVs is also costly and requires expertise, and it relies on large economies of scale that have not been developed in the United States. Regulatory and policy issues also increase the cost of transportation and handling of battery waste, which increases the cost for commercial recyclers—making it harder to recycle without the aid of federal subsidies. Another problem is the limited data surrounding recycling rates for critical minerals, as data in the US depends on voluntary business submissions and is highly variable.

Final Assessment

From mining to recycling, China dominates the battery supply chain from end to end. Ultimately, if this trend holds, US auto manufacturers will find their competitive edge eroding as the world transitions toward EVs. The Department of Defense, meanwhile, will continue to find itself reliant on Chinese battery cells. To ensure that its future economic and military competitiveness is not subject to Beijing, the United States and its allies and partners must build a more resilient advanced battery supply chain.



5. TOWARD A STRATEGIC APPROACH TO BATTERIES

To counter China's dominance in the battery industry, America must embrace a strategic approach to batteries. The United States can minimize Chinese leverage by embracing a limited form of supply chain decoupling. Going forward, this means focusing on boosting domestic mining, processing, and battery production, as well as advancing innovation. These lines of effort contribute to building a strong and resilient domestic manufacturing base. In particular, the United States needs a battery strategy that fully meets DOD's current and future needs, including a reliable and secure manufacturing base.

Evaluating the Biden Administration's Battery Blueprint

In February 2021, the Biden administration announced that it would undertake a 100-day supply chain review across four

strategic sectors: advanced batteries, active pharmaceutical ingredients, critical minerals and materials, and semiconductors. Each review was led by a separate executive agency, and in June, results were released in the form of a 250-page report (referred to here as the 100-Day Report). Findings from the batteries portion—which was conducted by the Department of Energy (DOE)—were included soon after in the form of a “National Blueprint for Lithium Batteries.”¹³³

Overall, the DOE Blueprint presents a detailed, whole-of-government strategy for building a robust, domestic-oriented bat-

Photo: Lithium Americas Corp. seeks to develop a major lithium mine in Thacker Pass, Nevada. (Carolyn Cole/*Los Angeles Times* via Getty Images)

tery supply chain within the next ten years. It calls for the use of various policy tools (coordinated across multiple agencies) to boost demand for EVs, ensure sustained supply of raw materials, and develop a domestic production base for batteries. The Blueprint also proposes jumpstarting battery recycling in the United States and supporting STEM education and workforce development.¹³⁴ These are all commendable goals.

And yet, while the strategy claims to meet “national security requirements,” it fails to approach batteries through a sufficiently strategic lens. At a recent public appearance, David Howell—director of the DOE Vehicle Technologies Office, which helped coordinate the Blueprint—noted that his agency is focused on two objectives: first, to decarbonize the transportation sector by 2050; and second to decarbonize the electricity sector by 2050.¹³⁵ These goals are certainly worthwhile, but if pursued on their own—without the priority placed on shifting the battery supply chain away from China—they might lead to an increased reliance on Beijing.¹³⁶

In addition, the 100-Day Report gives defense-related uses for batteries short shrift. The report focuses mainly on the commercial sector and offers few recommendations for building a supply chain specific to military batteries, which must be built to more extreme specifications than commercial, off-the-shelf batteries. Of the eighty-some pages in the 100-Day Report that cover batteries, defense-related uses are confined to just a few pages.¹³⁷

In the process, the report overlooks the many policy tools available to the Department of Defense to build out a domestic battery supply chain. Most notably, the Blueprint does not mention nodes in the Pentagon’s innovation ecosystem—including DARPA, AFWERX, or the Defense Innovation Unit, among others—that develop and procure battery technology for DOD. These pathways are crucial to bridging the gap between off-the-shelf products and defense needs, and they also provide important funding and partnership opportunities for innovation.

The Defense Production Act

The Defense Production Act (DPA) allows the president to exercise his emergency authority to control and re-direct private industry for national defense purposes. Passed in 1950, the DPA has been invoked over 50 times since.

The Act confers a number of authorities. Title I permits the executive branch to reprioritize contracts and “allocate materials, services, and facilities” to promote the national defense—provided an industry is both “critical” and “strategic.” Title III allows the president to offer financial incentives, including loans, loan guarantees, direct purchases, and purchase commitments to shore up industrial base capacity. Title VII, meanwhile, protects against anti-trust issues that might arise when the government award contracts and the associated funding to one company without competition.

During the early stages of the COVID-19 pandemic, the Trump administration invoked DPA Title III to increase production of masks and other personal protective equipment. Title III was also used to support various parts of the defense industrial base, including critical minerals production. In January 2021, for instance, DOD entered into an agreement with an Australian rare earths firm under Title III to construct a separation plant in the United States.

Strategic Objectives

Developing a strategic proposal for batteries starts with setting the right objectives. Rather than beginning with climate benchmarks, any national strategy for batteries should seek to achieve the following goals:

Reduce Beijing’s leverage in strategic tech sectors by embracing “selective decoupling.” Developing a domestic sup-

ply chain for lithium batteries means breaking Chinese bottlenecks in a strategic sector. As former Deputy National Security Advisor Matt Pottinger has explained, China's aggressive economic strategy—which involves establishing centrality in critical supply chains and weaponizing the ensuing dependence—means that “all of the areas that China has identified in its Made in China 2025 strategy” are sectors in which the US “should be proactively and selectively decoupling from.”¹³⁸

Develop power sources that offer new military capabilities, enabling DOD's shift toward distributed operations.

The Department of Defense is currently reshaping its force posture, doctrine, and strategy for great power competition and battery innovation is an important part of this shift. Better batteries will unlock new capabilities, like unmanned systems and electromagnetic warfare, that will loom large in any future conflict.

Support US economic leadership in the automobile industry. As noted above, the auto industry is America's largest manufacturing sector and contributes 3% to the US GDP. Each year, it purchases hundreds of billions of dollars' worth of US-produced raw materials, including rubber, steel, glass, and semiconductors.¹³⁹ According to the Center for Automotive Research, the industry “contributes to a net employment impact in the US economy of nearly 8 million jobs.”¹⁴⁰ As the world transitions toward EVs, remaining reliant on Chinese suppliers would set American automakers behind, dealing a significant blow to the US economy.

Policy Recommendations

To achieve these objectives, US policymakers should adopt a four-part strategy to create a secure, domestic-oriented supply chain for advanced batteries.

First, the United States should use available policy tools to make investments in mining, processing, and battery production, as well as battery recycling. Second, policymakers should deploy

tools that drive innovation in substitutes for Chinese-controlled critical minerals, next-generation battery technologies, and manufacturing techniques for lithium-ion batteries in order to leapfrog Chinese suppliers. Third, the Department of Defense should undertake a full review of its battery supply chain with an eye toward using DOD-specific policy tools that strengthen the industrial base for military batteries. Fourth, the US government should invest in workforce development and talent programs across the supply chain.

Some of these steps are already being taken, but the Hamilton Commission remains concerned that these activities are being approached from an insufficiently strategic lens. The strategy outlined below seeks to address this issue and offers specific recommendations for implementation.

I. Make and encourage investments in mining, processing, battery production, and recycling.

Like many twenty-first-century industries at the leading edge, battery production, as well as the mining and processing of critical minerals, is extremely capital intensive. Battery producers in particular face “wafer-thin margins and the assumption of large warranty liabilities.”¹⁴¹ For these reasons, “every major North American company that has looked at getting into the business of high-volume lithium-ion battery cell manufacturing over the last twelve years has taken a pass on the opportunity.”¹⁴² Given the strategic importance of batteries and their inputs, as outlined above, government support is necessary to build a robust American battery industry.

The US government should use diplomatic and economic tools to work with friendly countries to ensure a sustained source of critical minerals. To bring domestic sources online, DOE should offer incentives, especially loan guarantees, to mining and processing firms, cathode and anode manufacturers, and battery producers. These actions will signal sustained support for battery-related companies, which in turn would funnel private capital toward building a domestic supply chain.

The Biden administration should begin by:

- **Expanding the State Department's Energy Resources Governance Initiative (ERGI) to include additional partners, especially countries in the South American "Lithium Triangle."** Launched in 2019, ERGI is a State Department-led coalition designed to promote sound mining sector governance and resilient energy mineral supply chains. Current members include the US, Australia, Botswana, Canada, and Peru.

It may take ten to fifteen years before the United States can secure domestic access to the critical minerals used in batteries; therefore it must deepen collaboration with allies and partners to ensure continued access to these resources. The Biden administration has already expressed a willingness to expand ERGI, and reportedly views it as a key vehicle for procuring critical minerals for batteries. The Hamilton Commission applauds these efforts but they should not substitute for bringing domestic mining operations online.

To build production capacity for batteries and their inputs, the administration should:

- **Use the Federal Consortium on Advanced Batteries to fast-track the permitting process across the supply chain.** In China, cathode and anode manufacturing facilities often receive permits in six to nine months. In the United States the same process usually takes upwards of two years. Acquiring the needed permits for mining in the United States, meanwhile, can take roughly ten years.
- During the final weeks of the Trump administration, officials successfully fast-tracked permitting for Nevada's Thacker Pass Mine, the country's second domestic source of lithium. The Biden administration must ensure that fast-tracking continues across the supply chain, for mining as well as processing and production facilities.
- **Offer loan guarantees to domestic mining operations, processing firms, and cell manufacturers.** Establishing

new mining operations, processing facilities, and cell manufacturing plants can be extremely capital intensive. Loan guarantees can add an extra level of security for potential investors. The Biden administration has announced that it would revive the DOE's clean energy loan guarantee program, an Obama-era initiative that promised aid to renewable energy projects. While reviewing applications, DOE officials should prioritize projects that would reduce US dependence on China for critical minerals, cathode and anode materials, and battery cells.

- **Revitalize the 48C Clean Energy Manufacturing Tax Credit to promote the creation of battery megafactories and cathode and anode production facilities.** Manufacturing battery cells and cathode and anode materials in the United States is crucial to creating a domestic battery manufacturing ecosystem. Under the Obama administration, the 48C Clean Energy Manufacturing Tax Credit was created to provide government support for projects related to clean energy.

One significant weakness of the original 48C program was its failure to ensure that firms remain in the United States after receiving their tax credits. In 2016, the Obama administration could not prevent Carrier Corporation, an HVAC company which received credits to build natural gas furnaces, from closing its Indianapolis plant and relocating to Mexico.¹⁴³ The Biden administration must require that firms keep their operations in the United States in order to receive their credit. Alternatively, the government could expand the 48C program to provide battery corporations with an ongoing tax incentives for remaining domestic, outside a one-time, limited duration application process.

- **Use government incentives to boost domestic electrode coating sources.** Once the critical minerals needed for battery cells are combined, the resulting mixture must be sprayed onto sheets of metal foil. This process creates the electrode found in every lithium-ion battery. Electrode manufacturing is the second most expensive component in

the battery fabrication process, after the procurement of raw materials. There is an acute shortage of electrode manufacturing in the United States.

- **Assess the Federal Acquisition Regulation (FAR) and Defense Federal Acquisition Regulation Supplement (DFARS) to determine what changes might promote domestic battery development.** FAR and DFARS are sets of regulations that govern federal acquisition. Changing these regulations could shift the playing field away from Chinese battery manufacturers by requiring domestic or allied nation sourcing.

Until 2019, for example, DFARS did not require that magnets made from rare earth minerals come from an allied country, only that finished products did. This unintentionally granted preference to Chinese mining operations, which can offer lower prices thanks to lax environmental standards and heavy government support. Changes stipulated in the 2019 National Defense Authorization Act (NDAA) should, within a five-year transition period, promote domestic mining operations which have been undermined by Chinese pricing and other industrial policies.¹⁴⁴

The 100-Day Report and National Blueprint for Lithium Batteries each call for changes to FAR, but changes to DFARS are not mentioned in either document. The Federal Consortium on Advanced Batteries should coordinate with the Department of Defense to assess changes to DFARS that could promote domestic battery manufacturers.

- **Adjust tariffs on finished battery packs from China.** In 2018, when the Trump administration levied Section 301 tariffs on Chinese companies, battery cells, cobalt, lithium, and nickel imported from China were included on the level 1 list, meaning they remain subject to a 25% tariff. By contrast, finished battery packs were included on the level 4 list and are subject to an additional 7.5% duty.¹⁴⁵ The Section 301 China tariffs are still in force. To encourage domestic production, finished battery packs from Chinese manufacturers should be shifted to the level 1 list.

The Department of Energy should take steps to boost battery recycling, as outlined in the National Blueprint for Lithium Batteries. First steps should include:

- **Creating a national battery recycling initiative** To efficiently collect and recycle batteries at scale, the US should launch a national recycling initiative, coordinated by DOE. Through its robust system of loan guarantees totaling over \$40 billion, DOE should stimulate the production of domestic battery recycling plants. The DOE should also foster partnerships between battery producers and battery recyclers to further reduce the economic risk of starting recycling plants. Finally, DOE should award additional R&D grants for innovative battery recycling technologies and bring them to market through ARPA-E.
- **Reviewing federal regulations on transportation of lithium-ion batteries.** Due to potential safety risks, the transportation of lithium-ion batteries remains strictly regulated. However, many of these regulations are overly cumbersome, rendering the transportation of battery components costly and nearly impossible. Establishing a large-scale battery recycling capacity will require loosening these regulations. In particular, DOE should loosen regulations on the transport of “black mass”—the sludgy mix of nickel, magnesium, and cobalt from NMC-cathode based cells.
- **Instituting federal regulations requiring batteries be “built to recycle.”** The cells that make up battery packs are often welded into place, which greatly increases the cost and complexity of recycling efforts. The DOE should require battery manufacturers to rely on dissolvable adhesives and other methods to package battery cells.

II. Drive innovation in mineral substitutes, next-generation battery technologies, and manufacturing methods to minimize supply chain vulnerabilities and leapfrog Chinese suppliers.

In terms of production, US battery companies remain about a decade behind their Chinese competitors.¹⁴⁶ Catching up to and

eventually surpassing the Chinese will require carefully targeted government investment in battery innovation. Funding should be directed toward three main areas: finding substitutes for inputs controlled by China, such as cobalt and graphite; investing in potential breakthrough technologies; and developing novel, more efficient manufacturing processes for lithium-ion batteries.

The White House should:

- **Direct the US Commerce Department to include advanced lithium-ion and next-generation battery components on its list of “emerging and foundational technologies.”** As the US.–China Economic and Security Commission recently noted, the Commerce Department has yet to carry out its responsibility to compile a list of “emerging and foundational technologies,” as required under the 2018 Foreign Investment Risk Review Modernization Act (FIRRMA) and Export Control Reform Act (ECRA).¹⁴⁷

Lithium-ion and next-generation battery technology should be included on the final list. Adding these battery technologies to the list unlocks a slate of policy tools, including export controls, that an administration can use at its discretion.

The Department of Energy should focus additional resources on:

- **Achieving substitution for cobalt-heavy cathode chemistries.** The nickel-magnesium-cobalt (NMC) cathode chemistry is a popular choice for battery cell manufacturers because it offers high energy density and reliability. Unfortunately, cobalt is expensive, rare, and subject to human rights concerns. The DOE is currently working to develop and commercialize reduced cobalt cathode chemistries, but this goal remains two to four years away.
- **Achieving substitution for graphite anodes.** Today’s lithium-ion batteries usually feature a graphite-based anode, and as noted above, China produces some 80% of the world’s spherical graphite and 100% of global synthetic graphite. Breaking this monopoly would be costly, to the

point where it would make more sense to seek alternatives. One potential solution is silicon anodes—silicon is more widely available than graphite and other critical minerals, though production is also clustered in China. Another option might be solid-state batteries, which use a lithium metal anode.

The Department of Energy should encourage innovation in next-generation batteries by:

- **Creating a one-time \$10 million prize for the most significant advance in next-generation battery storage technology.** DOE is currently running a \$5.5 million prize competition for advances in battery recycling. Awarding a major prize for innovation in next-generation batteries could help identify technologies that could overtake Chinese suppliers. This effort could be coordinated with the DOE’s Energy Storage Grand Challenge (ESGC).¹⁴⁸ Submissions should be required to include a draft roadmap to commercialize the technology, as well as a consideration of the technology’s relevance to the Department of Defense.
- **Significantly boosting basic and applied research funding for beyond lithium-ion battery chemistries.** Significant R&D funding should be directed toward achieving, then commercializing, a breakthrough in novel battery chemistries. As of FY2019, DOE appears to be spending about \$35 million on R&D for beyond lithium-ion battery technology.¹⁴⁹ Funding should be increased significantly. Technologies to investigate include solid-state and flow batteries, as well as lithium-sulfur batteries and silicon anodes. First-mover advantage in one of these areas could significantly disrupt the Chinese battery quasi-monopoly.
- **Boosting ARPA-E funding, but dropping support for a “Climate DARPA.”** Launched in 2009, the Advanced Research Projects Agency – Energy (ARPA-E) aims to help energy programs bridge the “valley of death” between innovation in the lab and the commercial market. The agency has

proven effective, with projects funded by ARPA-E “five times more likely to produce a patent and scientific publication than projects funded by other R&D programs at DOE.”¹⁵⁰

The Biden administration seeks to create ARPA-C, a research agency modeled on DARPA, but focused solely on addressing climate change, and split funding between the new agency and ARPA-E.¹⁵¹ Given that that ARPA-E grants already focus on developing alternative sources of clean energy, a new agency would create redundancy and stretch resources; instead, additional funding should be channeled to ARPA-E.

In case next-generation battery technologies disappoint or never materialize, the White House should:

- **Significantly increase the DOE’s Advanced Manufacturing Office budget to boost funding for improved manufacturing techniques for lithium-ion batteries.** Battery consortium NAATBatt International recently concluded that lithium-ion technology will remain relevant, regardless of whether new battery chemistries enter the market.¹⁵² Thus, developing more efficient manufacturing techniques for lithium-ion batteries can help reduce Beijing’s hold on the advanced battery industry. Funding the DOE’s Advanced Manufacturing Office could help shepherd new manufacturing techniques through the technology valley of death.

III. Use DOD tools to strengthen the supply chain for military batteries, with a goal of putting new capabilities in the field.

As detailed above, batteries carry a wide variety of implications for national defense, from powering unmanned systems and directed-energy weapons to providing power sources for satellites. DOD must therefore take steps to secure the supply chain for military-grade batteries, which are built to more extreme specifications than off-the-shelf versions. DOD has a wide variety of policy tools at its disposal to accomplish this.

DOD should begin by adopting a more strategic approach to batteries. First steps would include:

- **Initiating a defense industrial base review on batteries for military applications, then integrating results into the upcoming Operational Energy Strategy.** The advanced batteries portion of the Biden administration’s supply chain review, coordinated by the Department of Energy, did not sufficiently address the important role that batteries play in national defense. DOD is required by Congress to release an Operational Energy Strategy report every four years. The most recent report was issued in 2016.¹⁵³ DOD should undertake a department-wide review of challenges faced by domestic manufacturers of military batteries and integrate them into the upcoming Operational Energy Strategy.
- **Reworking DOD’s approach to energy supply chains by investing in decentralized power generation.** Until DOD develops alternative power sources, the US military will remain reliant on increasingly brittle fuel supply chains. Instead, DOD needs mobile power sources that can generate energy in the field. Meeting DOD’s energy needs will require a variety of sources, including solar energy and bioreactors (see Energy Storage, Distributed Operations, and Power Generation, inset).

DOD, working in tandem with the White House, should use its policy tools to bolster battery production directly. This includes:

- **Reshoring military-grade battery production under the auspices of Title III of the Defense Production Act (DPA).** The DPA gives the president broad authority to “ensure the timely availability of essential domestic industrial resources to support national defense and homeland security requirements through the use of highly tailored economic incentives. Specifically, the program is designed to create, maintain, protect, expand, or restore domestic industrial base capabilities.”¹⁵⁴ This should include advanced battery production and manufacturing in the United States. In 2014, for example, this

authority was used to fund the Lithium-Ion Battery for Military Applications (LIMA) project to establish a long-term, viable, world-class domestic manufacturer of advanced lithium-ion batteries “that would be responsive to customer requirements with respect to performance, reliability, quality, delivery, and price.”¹⁵⁵ This project needs to be expanded and made a defense industrial base priority.

DOD should update acquisition and procurement processes for military-grade batteries by:

- **Eliminating the use of “lowest priced, technically acceptable” awards in Pentagon battery procurement.** Extreme requirements for military batteries prevent battery manufacturers from using commercial-grade battery cells, which drives up costs for domestic battery firms. This grants foreign cell manufacturers an edge over American producers. Instead of procuring the least expensive batteries that meet technical requirements, DOD should procure batteries via trade-off analysis, which would promote higher quality battery cells that provide operational advantages. Such an approach would benefit US firms that specialize in manufacturing batteries that meet DOD requirements.
- **Establishing a public–private partnership for military-optimized batteries and standardize battery specifications across the services.** The US military employs thousands of different types of batteries. A public–private partnership—dedicated explicitly to military-optimized batteries—should work with domestic manufacturers to establish battery standards for future platforms. This would allow manufacturers to produce “families” of similar-sized military-optimized lithium cells at scale, lowering costs for both firms and DOD.

DOD should foster innovation in military-grade batteries by:

- **Establishing a new Institute of Battery Manufacturing and Innovation (IBMI) as part of the Manufacturing Technology Program at the Department of Defense.**

The ManTech program’s nine existing institutes fund innovative manufacturing methods for a range of advanced technologies required by DOD and its contractors. A tenth institute devoted to advanced batteries would be a cost-effective way to increase battery R&D geared specifically to the needs of the military.

To bridge the valley of death, IBMI should also mediate collaboration between R&D entities and production facilities to drive licensing of new battery designs and chemistries.

- **Building a “BATTFab” facility to allow smaller companies to prototype and test battery designs and rapidly scale manufacturing.** Drawing from the example of the large-scale fabs used by the semiconductor industry, DOD should establish a battery fabrication facility open exclusively to US-based startups. Battery fabrication facilities are expensive to build. A BATTFab would allow smaller companies with limited capital to prototype and test their products, reducing development costs and improving consistency in the test equipment, processes, and methodologies across prototyping, production, assembly, and end-unit qualification. DOD should also explore using other transaction authorities to increase speed to market.

IV. Invest in workforce development and talent programs across the supply chain.

Designing and producing batteries and their inputs takes years of specialized training. The United States faces a serious shortage of talent in critical mining and processing; cathode, anode, and electrode production; and battery engineering and manufacturing. Policymakers should address this challenge by cultivating domestic talent, and by bringing in foreign expertise as necessary.

The Federal Consortium on Advanced Batteries should work with relevant agencies to:

- **Create a job training program for critical mineral mining, processing, and operations.** Executives at the recently approved Thacker Pass lithium mine in Nevada have

spoken openly about the challenges of fielding the skilled workers required to run their facility. To create the necessary talent pool, they have begun working with the local community college and school district. Congress and DOE should work with industry, union leadership, and leading technical universities to develop a national initiative for promoting careers in mining engineering for critical minerals, from advanced degrees to on-the-job training.

- **Create a scholarship fund for aspiring US battery engineers.** A scholarship fund linked to America's top tech universities could bring aspiring students to a field that promises to be among the most important in advancing the future of clean renewables. Such a program should provide additional funding to schools that create an interdisciplinary battery engineering major, which would combine mechanical, electrical, chemical, and electro-chemical engineering, as well as advanced manufacturing expertise.

- **Working with allied and partner countries to build the US battery workforce.** The fact that the United States has few workers capable of operating advanced processing and battery manufacturing equipment explains the recent boom in joint-venture arrangements between US automakers and foreign battery firms. In 2020, for example, GM announced that it would partner with South Korean battery manufacturer LG Chem to produce battery cells to power the automaker's EV lineup.¹⁵⁶

To supplement these private sector efforts, the Federal Consortium on Advanced Batteries should create a critical mineral and battery production exchange program, led by the State Department, that taps into the wealth of expertise from battery-making countries like Germany, Japan, and South Korea. Such a program could take a page from the US.–Japan Competitiveness and Resilience (CoRe) Partnership, which includes cooperation “on sensitive supply chains, including semi-conductors, and on the promotion and protection of critical technologies.”¹⁵⁷



6. CONCLUSION

Today's world is changing at a dizzying pace. In the energy sector, the shift toward EVs and renewable energy promises to remake some of the world's largest industries. The CCP intends to capitalize on this change. Chinese grand strategy hinges on the assumption that, in our technology-driven world, a country's ability to control market share, domestic production, and international standards in high technology sectors has become perhaps the most important factor in calculating national power. This belief is driving CCP efforts to "seize the commanding heights" in advanced technologies, including batteries and EVs.

As Xi's push for self-sufficiency and "indigenous innovation" demonstrates, Beijing has embraced the logic of decoupling: the CCP seeks to bolster China's national power by means of zero-sum technological and economic leadership, throwing

the process of globalization into reverse. The United States has no choice but to reciprocate. Given the importance of batteries as a source of geopolitical leverage, as a crucial enabler of next-generation defense concepts, and as the key to competition for economic leadership in the EV industry, breaking Chinese bottlenecks in critical mineral production and battery manufacturing must be a strategic imperative for the United States.

To break free of Chinese leverage, American policymakers must communicate and implement a national battery strategy

Photo: A pilot plant technician works at a Lithium Americas Corp. facility in Reno, Nevada on June 7, 2021. (Carolyn Cole/*Los Angeles Times* via Getty Images)

that builds a domestic supply chain for advanced batteries, but this strategy must be approached through the lens of geopolitics. Such a strategy should include the four steps outlined in this report: (1) provide US government support for critical mineral mining and processing, battery and cell production, and battery recycling; (2) offer additional US government funding to boost innovation in cobalt- and graphite-less chemistries, next-generation batteries, and manufacturing techniques for lithium-ion batteries through targeted investments; (3) Create DOD initiatives to secure the supply chain for military-grade

batteries; and (4) invest in workforce and talent development programs.

Whether the United States can successfully implement and resource this strategy is another matter. Ultimately, this may be a question of will—establishing a more resilient battery supply chain will require years of sustained effort from dedicated policymakers. If the US intends to win the battery race, reframing energy policy as another front in the US–China strategic competition is a crucial first step.

ENDNOTES

- 1 Michael Woodward, Jamie Hamilton, and Bryn Walton, "Electric Vehicles: Setting A Course for 2030," Deloitte, July 28, 2020, <https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html>.
- 2 Ira Boudway, "Batteries For Electric Cars Speed Toward a Tipping Point," Bloomberg, December 16, 2020, <https://www.bloomberg.com/news/articles/2020-12-16/electric-cars-are-about-to-be-as-cheap-as-gas-powered-models>.
- 3 Benchmark Mineral Intelligence, "Lithium-Ion Battery Megafactory Assessment," March 2021, <https://www.benchmarkminerals.com/megafactories/>; Federal Consortium for Advanced Batteries, "National Blueprint for Lithium Batteries: 2021-2030," June 7, 2021, <https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries>, p. 12.
- 4 Jeanne Whalen, "Biden Wants to Create Millions of Clean-Energy Jobs. China and Europe Are Way Ahead of Him", The Washington Post, February 11, 2021, <https://www.washingtonpost.com/technology/2021/02/11/us-battery-production-china-europe/>.
- 5 Patrick Bernard, "Three Battery Technologies That Could Power the Future," Saft, accessed August 4, 2021, <https://www.saftbatteries.com/media-resources/our-stories/three-battery-technologies-could-power-future>.
- 6 Micah S. Ziegler and Jessika E. Trancik, "Re-Examining Rates of Lithium-Ion Battery Technology Improvement and Cost Decline," *Energy & Environmental Science* 14 (2021): p. 1635-1651, <https://pubs.rsc.org/en/content/articlepdf/2021/ee/d0ee02681f?page=search>.
- 7 Clean Energy Institute, "Lithium-Ion Battery," University of Washington, accessed August 4, 2021, <https://www.cei.washington.edu/education/science-of-solar/battery-technology/>.
- 8 Bernard, "Three Battery Technologies That Could Power the Future," Saft, <https://www.saftbatteries.com/media-resources/our-stories/three-battery-technologies-could-power-future>.
- 9 Green Car Congress, "Solid Power Unveils All-Solid-State Platform Technology, Transitions Silicon Cells to Pilot Line," May 25, 2021, <https://www.greencarcongress.com/2021/05/20210525-solidpower.html>.
- 10 Tim Kelley and Sayantani Ghosh, "Explainer: How Will Solid-State Batteries Make Electric Vehicles Better?", Reuters, September 7, 2021, <https://www.reuters.com/technology/how-will-solid-state-batteries-make-electric-vehicles-better-2021-09-07/>.
- 11 Lester R. Brown, *The Great Transition: Shifting from Fossil Fuels to Solar and Wind Energy* (New York: W. W. Norton & Company, 2015).
- 12 The White House, "Carbis Bay G7 Summit Communique," [whitehouse.gov](https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/13/carbis-bay-g7-summit-communique/), June 13, 2021, <https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/13/carbis-bay-g7-summit-communique/>.
- 13 Florence Tan and Chen Aizhu, "Pandemic's 'Great Reset' Makes Energy Firms Invest More in Renewables – Executives," Reuters, September 15, 2020, <https://www.reuters.com/article/uk-oil-appec-energy-transition/pandemics-great-reset-makes-energy-firms-invest-more-in-renewables-executives-idUKKBN-2660HO>.
- 14 Paul Takahashi, "BP Is Embracing Energy Transition, CEO Says at CERAWEEK," Houston Chronicle, March 1, 2021, <https://www.houstonchronicle.com/business/energy/article/Oil-companies-can-t-fight-energy-transition-15988740.php>; Clifford Krauss, "Exxon Mobil's Chief Says It Is 'Supportive' of Zero-Emission Goals," The New York Times, March 3, 2021, <https://www.nytimes.com/2021/03/03/business/energy-environment/exxon-mobil-darren-woods.html>.
- 15 Timothy Puko, "Oil Company Leaders Support Carbon Pricing Plan," The Wall Street Journal, March 22, 2021, <https://www.wsj.com/articles/oil-company-leaders-support-carbon-pricing-plan-11616454002>.
- 16 Sarah Ladislav, "Lessons from a Strategy of Energy Dominance," *Oxford Energy Forum* 126 (February 2021), p. 43.
- 17 Jeff Barron, "China's Crude Oil Imports Surpassed 10 Million Barrels Per Day in 2019," US Energy Information Administration, March 23, 2020, <https://www.eia.gov/todayinenergy/detail.php?id=43216>.
- 18 Reuters Staff, "Factbox: Asia Region Is Most Dependent on Middle East Crude Oil, LNG Supplies," Reuters, January 8, 2020, <https://www.reuters.com/article/asia-mideast-oil-factbox/factbox-asia-region-is-most-dependent-on-middle-east-crude-oil-lng-supplies-idINKBN1Z71VW>.
- 19 Center for Strategic and International Studies, "How Much Trade Transits the South China Sea?", China Power Project, August 2, 2017, <https://chinapower.csis.org/much-trade-transits-south-china-sea/>.
- 20 Council on Foreign Relations, "China's Belt and Road: Implications for the United States," Independent Task Force Report No. 79, March 2021, <https://www.cfr.org/report/chinas-belt-and-road-implications-for-the-united-states/>.
- 21 Xinhua, "Feature: Green Is Gold – Xi Jinping Innovates Fight Against Climate Change," April 22, 2021, http://www.xinhuanet.com/english/2021-04/22/c_139898299.htm.
- 22 See Te-Ping Chen, "China's Water Problems are Even Worse than You Think: Report," The Wall Street Journal, January 13, 2015, <https://www.wsj.com/articles/BL-CJB-25611>; also see "China: Impact of Climate Change to 2030," US National Intelligence Council, prepared by Joint Global Change Research Institute and Battelle Memorial Institute, Pacific Northwest Division, April 2009, [dni.gov/files/documents/climate2030_china.pdf](https://www.dni.gov/files/documents/climate2030_china.pdf).
- 23 Cindy Hurst, "For the US, Starting a Rare Earth Mine Is the Easy Part," The New York Times, November 9, 2010, <https://www.nytimes.com/roomfordebate/2010/11/08/can-the-us-compete->

- on-rare-earths/for-the-us-starting-a-rare-earth-mine-is-the-easy-part.
- 24 The Economist, "Rare Earths Give China Leverage in the Trade War, at a Cost", June 15, 2019, <https://www.economist.com/china/2019/06/15/rare-earths-give-china-leverage-in-the-trade-war-at-a-cost>.
 - 25 "Indigenous innovation" was reintroduced as a goal in China's 2006 Medium and Long Term Technology plan. See Nathaniel Ahrens, "China's Industrial Policymaking Process," CSIS, January 2013, https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/130124_Ahrens_ChinaPolicymaking_Web.pdf, p. 37. Also see Robert D. Atkinson, "China's Strategy for Global Technology Dominance by Any Means Necessary," *Forbes*, November 12, 2015, <https://www.forbes.com/sites/realspin/2015/11/12/chinas-strategy-for-global-technology-dominance-by-any-means-necessary/?sh=797d8169562a>.
 - 26 People's Daily Online, "Core Technology Depends on One's Own Efforts: Xi Jinping," April 19, 2018, <http://en.people.cn/n3/2018/0419/c90000-9451186.html>.
 - 27 Abigail Coplin, Paul Triolo, Elsa Kania, Rui Zhong, John Lee, and Benjamin Larsen, "Experts: Xi's Science and Technology Speech Echoes and Updates Deng Xiaoping," *New America*, September 23, 2020, <https://www.newamerica.org/cybersecurity-initiative/digichina/blog/experts-xis-science-and-technology-speech-echoes-and-updates-deng-xiaoping/>.
 - 28 Oxford Institute for Energy Studies, "Key issues for China's 14th Five Year Plan," March 2021, <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/03/Key-issues-for-Chinas-14th-Five-Year-Plan.pdf>.
 - 29 Jude Blanchette and Andrew Polk, "Dual Circulation and China's New Hedged Integration Strategy," CSIS, August 24, 2020, <https://www.csis.org/analysis/dual-circulation-and-chinas-new-hedged-integration-strategy>.
 - 30 Craig Addison, "A 'Silicon Shield' Protects Taiwan from China," *The New York Times*, September 29, 2000, <https://www.nytimes.com/2000/09/29/opinion/IHT-a-silicon-shield-protects-taiwan-from-china.html>.
 - 31 Bryn Walton et al., "Electric Vehicles: Setting A Course for 2030," *Deloitte*, July 28, 2020, <https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html>.
 - 32 American Automakers, "US Economic Contributions," AAPC, <https://www.americanautomakers.org/us-economic-contributions>.
 - 33 Ibid.
 - 34 Kim Hill, Adam Cooper, and Debra Menk, "Contribution of the Automotive Industry to the Economies of all Fifty State and the United States," Center for Automotive Research, April 2010, <https://www.cargroup.org/wp-content/uploads/2017/02/CONTRIBUTION-OF-THE-AUTOMOTIVE-INDUSTRY-TO-THE-ECONOMIES-OF-ALL-FIFTY-STATES-AND-THE-UNITED-STATES.pdf>.
 - 35 Walton et al., "Electric Vehicles: Setting A Course for 2030," *Deloitte*, July 28, 2020, <https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html>.
 - 36 Ibid.
 - 37 Thomas Gersdorf et al., "McKinsey Electric Vehicle Index: Europe Cushions a Global Plunge in EV Sales," *McKinsey and Company*, July 17, 2020, <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales>.
 - 38 Steven Mufson, "General Motors to Eliminate Gasoline and Diesel Light-Duty Cars and SUVs by 2035," *Washington Post*, January 28, 2021, <https://www.washingtonpost.com/climate-environment/2021/01/28/general-motors-electric/>.
 - 39 Jim Motavalli, "Every Automaker's EV Plans Through 2035 and Beyond," *Forbes*, July 26, 2021, <https://www.forbes.com/wheels/news/automaker-ev-plans/>.
 - 40 Mufson, "General Motors to Eliminate Gasoline and Diesel Light-Duty Cars and SUVs by 2035," *Washington Post*, <https://www.washingtonpost.com/climate-environment/2021/01/28/general-motors-electric/>.
 - 41 The White House, "FACT SHEET: President Biden Announces Steps to Drive American Leadership Forward on Clean Cars and Trucks," August 5, 2021, [whitehouse.gov](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/), <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/>.
 - 42 Walton et al., "Electric Vehicles: Setting A Course for 2030," *Deloitte*, July 28, 2020, <https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html>.
 - 43 Ibid.
 - 44 Federal Consortium on Advanced Batteries, "Executive Summary: National Blueprint for Lithium Batteries: 2021-2030," June 2021, <https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries>, p. 12.
 - 45 See Nadia Schadow, "Trading One Dependency for Another," *War on the Rocks*, May 12, 2021, <https://warontherocks.com/2021/05/trading-one-dependency-for-another/>.
 - 46 David P. Goldman, "What China Learned from Cold War America," *The Wall Street Journal*, July 24, 2020, <https://www.wsj.com/articles/what-china-learned-from-cold-war-america-11595618253>.
 - 47 US Senate Committee on Small Businesses & Entrepreneurship, "Made in China 2025 and the Future of American Industry," Project for Strong Labor Markets and National Development, <https://www.rubio.senate.gov/public/files/Rubio-China-2025-Report.pdf>, p. 30 (see note).
 - 48 Yao Lu, "China Releases 12th Five-Year Plan to Nation-

- al Strategic Emerging Industries,” China Briefing, July 25, 2012, <https://www.china-briefing.com/news/china-releases-12th-five-year-plan-for-national-strategic-emerging-industries/>.
- 49 US Congress, US-China Economic and Security Review Commission, “China’s Five-Year Plan, Indigenous Innovation and Technology Transfers and Outsourcing,” 112th Congress, 1st session, June 15, 2011, <https://www.uscc.gov/sites/default/files/transcripts/6.15.11HearingTranscript.pdf>, p. 29.
- 50 Ibid, p. 26.
- 51 US Chamber of Commerce, “Made in China 2025: Global Ambitions Built on Local Protections,” March 2017, https://www.uschamber.com/sites/default/files/final_made_in_china_2025_report_full.pdf.
- 52 US Senate Committee on Small Businesses & Entrepreneurship, “Made in China 2025 and the Future of American Industry,” p. 31.
- 53 International Energy Agency, “Global Electric Car Sales by Key Markets, 2010-2020,” December 2, 2020, <https://www.iea.org/data-and-statistics/charts/global-electric-car-sales-by-key-markets-2015-2020>.
- 54 Arjun Kharpal, “Power Is ‘Up for Grabs’: Behind China’s Plan to Shape the Future of Next-Generation Tech,” CNBC, April 26, 2020, <https://www.cnbc.com/2020/04/27/china-standards-2035-explained.html>.
- 55 Mark Kane, “China to Introduce EV Wireless Charging Standard Based on WiTricity Technology,” InsideEVs, May 9, 2020, <https://insideevs.com/news/420700/china-ev-wireless-charging-standard-witricity-tech/>.
- 56 Cao Yingying, “New Standards Released for Electric Car Batteries,” China Daily, May 8, 2020, https://www.chinadaily.com.cn/a/202005/18/WS5ec1e22aa310a8b241156558_1.html.
- 57 Lindsay Gorman, “Pineapple War Shows Taiwan Won’t Be Bullied by Beijing,” Foreign Policy, March 16, 2021, <https://foreignpolicy.com/2021/03/16/taiwan-china-pineapple-war-economic-bullying-democracies-boycott/><https://www.wsj.com/articles/u-s-is-vulnerable-to-chinas-dominance-in-rare-earths-report-finds-11593423003>; Emily de La Bruyère and Nathan Picarsic, “Absolute Competitive Advantage: Rare Earth Elements in China’s Strategic Planning,” Horizon Advisory, June 2020, https://issuu.com/horizonadvisory/docs/horizon_advisory_-_absolute_competitive_advantage_.
- 58 Fergus Hanson, Emilia Currey, and Tracy Beattie, “The Chinese Communist Party’s Coercive Diplomacy,” Australian Strategic Policy Institute, August 2020, <https://www.aspi.org.au/report/chinese-communist-partys-coercive-diplomacy>.
- 59 Keith Bradsher, “Amid Tension, China Breaks Off Vital Exports to Japan,” The New York Times, September 22, 2010, <https://www.nytimes.com/2010/09/23/business/global/23rare.html>.
- 60 Keith Johnson and Elias Groll, “China Raises Threat of Rare-Earths Cutoff to US,” Foreign Policy, January 1, 2019, <https://foreignpolicy.com/2019/05/21/china-raises-threat-of-rare-earth-mineral-cutoff-to-us/>.
- 61 Bloomberg, “China May Ban Rare Earth Tech Exports on Security Concerns,” February, 19, 2021, <https://www.bloomberg.com/news/articles/2021-02-19/china-may-ban-rare-earth-technology-exports-on-security-concerns?sref=boE5Wq9G>. Recent threats have focused more heavily on the technology needed to process rare earths, rather than supplies of the minerals themselves.
- 62 Matt Pottinger, “Beijing’s American Hustle,” Foreign Affairs, August 23, 2021, <https://www.foreignaffairs.com/articles/asia/2021-08-23/beijings-american-hustle>; Rush Doshi, *The Long Game: China’s Grand Strategy to Displace American Order* (Oxford: Oxford University Press, 2021).
- 63 US Department of Defense, “Summary of the 2018 National Security Strategy,” <https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>, p. 1.
- 64 Aaron Mehta, “Portable Nuclear Reactor Project Moves Forward at Pentagon,” DefenseNews, March 23, 2021, <https://www.defensenews.com/smr/energy-and-environment/2021/03/23/portable-nuclear-reactor-project-moves-forward-at-pentagon/>.
- 65 S. Clinton Hinote, “Reimagining Energy for the Department of Defense” (keynote, AFWERX Reimagining Energy Showcase, virtual event, February 9, 2021), <https://reimaginingenergy.afwerx.com/>.
- 66 Adam Tiffen, “Going Green on the Battlefield Saves Lives,” War on the Rocks, May 22, 2014, <https://warontherocks.com/2014/05/going-green-on-the-battlefield-saves-lives/>.
- 67 Steve Hargreaves, “Ambushes Prompt Military to Cut Energy Use,” CNN Money, August 16, 2011, https://money.cnn.com/2011/06/14/news/economy/military_energy_strategy/index.htm; Tim Ash and Andrew Erdmann, “Powering the US Military: An Interview with the Pentagon’s Sharon Burke,” McKinsey & Company, April 1, 2013, <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/powering-the-us-military>.
- 68 US code defines operational energy as “energy required for training, moving, and sustaining military forces and weapons platforms for military operations.” See 10 US Code § 2924.
- 69 Bill Lynn, “Energy for the War Fighter: The Department of Defense Operational Energy Strategy,” The White House, June 14, 2011, <https://obamawhitehouse.archives.gov/blog/2011/06/14/energy-war-fighter-department-defense-operational-energy-strategy>.
- 70 Ash and Erdmann, “Powering the US Military,” McKinsey & Company, <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/powering-the-us-military>.
- 71 Ibid.
- 72 Robert H. Scales, “Russia’s Superior New Weapons,” The Washington Post, August 5, 2016, <https://www.washingtonpost.com/opinions/global-opinions/russias-superior-new-weapon>

ons/2016/08/05/e86334ec-08c5-11e6-bdcb-0133da18418d_story.html.

- 73 Andrew Krepinevich, Barry Watts, and Robert Work, "Meeting the Anti-Access and Area-Denial Challenge," CSBA, May 20, 2003, <http://csbaonline.org/publications/2003/05/a2ad-anti-access-area-denial/>.
- 74 Marine Corps Warfighting Laboratory, Futures Assessment, "Tentative Manual for Expeditionary Base Operations," <https://www.mcvl.marines.mil/TMEABO/>; Congressional Research Service, "Defense Primer: Army Multi-Domain Operations (MDO)," April 22, 2021, <https://fas.org/sgp/crs/natsec/IF11409.pdf>; Ronald O'Rourke, Congressional Research Service, "Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress," July 24, 2019, https://www.everycrsreport.com/files/20190724_RL32665_7bea2e4f25267bb1883fa3ecd1583d268bf457a.pdf.
- 75 John M. Doyle, "Berger Says Supporting a Widely Distributed Maritime Force Will Be a Challenge," *Sea Power*, May 14, 2021, <https://seapowermagazine.org/berger-says-supporting-a-widely-distributed-maritime-force-will-be-a-challenge/>.
- 76 Arthur Herman and Nadia Schadow, "A Good Battery Is the Best Defense Against a Military Assault," *The Wall Street Journal*, March 30, 2021, <https://www.wsj.com/articles/a-good-battery-is-the-best-defense-against-a-military-assault-11617136935>.
- 77 Marc D. Gietter, "Viewpoint: Offshore Battery Production Poses Problem for Military," *National Defense*, November 8, 2018, <https://www.nationaldefensemagazine.org/articles/2018/11/8/offshore-battery-production-poses-problems-for-military>.
- 78 Beth Reece, "New Batteries from DoD Agency Boosts Performance, Safety for Military Weapons Systems," *Defense News*, June 25, 2018, <https://www.defensenews.com/opinion/commentary/2018/06/25/new-batteries-from-dod-agency-boosts-performance-safety-for-military-weapons-systems/>.
- 79 US Department of Energy, Office of Energy Efficiency and Renewable Energy, "Federal Consortium on Advanced Batteries (FCAB)," accessed September 10, 2021, <https://www.energy.gov/eere/vehicles/federal-consortium-advanced-batteries-fcab>.
- 80 Joe Gould, "All-Electric Brigades? US Army Official Says It's Coming Sooner Than You'd Think," *Defense News*, October 11, 2017, <https://www.defensenews.com/digital-show-dailies/ausa/2017/10/11/all-electric-brigades-us-army-official-says-its-coming-sooner-than-you-d-think/>.
- 81 Iain McKinnie, "High-Energy Laser Weapon Systems," *Aerospace & Defense Technology*, June 1, 2020, <https://www.aerodefense-tech.com/component/content/article/adt/features/articles/37108>.
- 82 T'Jae Gibson, "Army Unburdens Soldiers Through Battery Innovations," *Army Research Laboratory Public Affairs*, June 16, 2011, https://www.army.mil/article/53283/army_unburdens_soldiers_through_battery_innovations.
- 83 Dorothy Robyn and Jeffrey Marqusee, "Clean Power from the Pentagon," *Issues in Science and Technology* 35, no. 4 (Summer 2019): p. 63-68, <https://issues.org/clean-power-from-the-pentagon/>.
- 84 Chris Wack, "Enovix Gets Lithium-Ion Battery Contract From US Defense Department," *MarketWatch*, July 15, 2021, <https://www.marketwatch.com/story/enovix-gets-lithium-ion-battery-contract-from-u-s-defense-department-271626351529>.
- 85 Jon Harper, "Pentagon Gets \$7.5 Billion for Unmanned Systems," *National Defense*, May 27, 2021, [https://www.nationaldefensemagazine.org/articles/2021/5/27/pentagon-gets-\\$7-5-billion-for-unmanned-systems](https://www.nationaldefensemagazine.org/articles/2021/5/27/pentagon-gets-$7-5-billion-for-unmanned-systems).
- 86 Ashleigh Townsend et al., "A Comprehensive Review of Energy sources for Unmanned Aerial Vehicles, Their Shortfalls and Opportunities for Improvements," *Heliyon* 6, no. 11 (November 2020), <https://www.sciencedirect.com/science/article/pii/S2405844020321289#:~:text=The%20main%20advantages%20of%20battery,and%20comparably%20low%20energy%20densities>.
- 87 Mohamed Nadir Boukoberinea, Zhibin Zhou, and Mohamed Benbouzid, "A Critical Review on Unmanned Aerial Vehicles Power Supply and Energy Management: Solutions, Strategies, and Prospects," *Applied Energy* 255 (December 2019), <https://doi.org/10.1016/j.apenergy.2019.113823>, p. 14.
- 88 Department of Defense, "FY2009–2034 Unmanned Systems Integrated Roadmap," 2009.
- 89 US Army, UAS Center of Excellence, "Eyes of the Army: US Army Roadmap for Unmanned Aircraft Systems 2010-2035," 2009, <https://irp.fas.org/program/collect/uas-army.pdf>.
- 90 Pat Host, "MQ-Next: The USAF Next-Generation Multirole UAS Programme," *Jane's Defence Weekly*, August 31, 2021, <http://s3.amazonaws.com/media.hudson.org/MQ-Next%20The%20USAF%20Next-Generation%20Multirole%20UAS%20programme.PDF>.
- 91 Rolls-royce.com, "A New Age of Aircraft Propulsion," accessed September 8, 2021, <https://www.rolls-royce.com/products-and-services/electrical/propulsion.aspx>.
- 92 Host, "MQ-Next: The USAF Next-Generation Multirole UAS Programme," <http://s3.amazonaws.com/media.hudson.org/MQ-Next%20The%20USAF%20Next-Generation%20Multirole%20UAS%20programme.PDF>.
- 93 Kelsey Reichmann, "Air Force Looks to Hybrid Electric Solution for eVTOL and UAS Energy Concerns," *Aviation Today*, March 4, 2021, <https://www.aviationtoday.com/2021/03/04/air-force-looks-hybrid-electric-solution-evtol-uas-energy-concerns/>.
- 94 United States Institute of Peace, *Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission*, November 13, 2018, <https://www.usip.org/sites/default/files/2018-11/providing-for-the-common-defense.pdf>, p. 41.

- 95 John R. Hoehn, Congressional Research Service, "US Military Electronic Warfare Program Funding: Background and Issues for Congress," April 16, 2020, <https://sgp.fas.org/crs/natsec/R45756.pdf>; US Department of Defense, "Electromagnetic Spectrum Superiority Strategy," October 2020, https://media.defense.gov/2020/Oct/29/2002525927/-1/-1/0/ELECTROMAGNETIC_SPECTRUM_SUPERIORITY_STRATEGY.PDF.
- 96 Department of Defense, Joint Publication 3-85, Joint Electromagnetic Spectrum Operations (Washington, DC: Department of Defense, 2020), https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_85.pdf.
- 97 Ibid, p. GL-6. See also Henry Obering, "Directed Energy Weapons Are Real...and Disruptive," Prism 8, no. 3 (January 2020), https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Obering_36-46.pdf.
- 98 Oriana Pawlyk, "Air Force's THOR Microwave Weapon Instantly Ends Enemy Drone Attack in New Video," Military.com, June 21, 2021, <https://www.military.com/daily-news/2021/06/21/air-forces-thor-microwave-weapon-instantly-ends-enemy-drone-attack-new-video.html>.
- 99 J.R. Wilson, "Laser Weapons Get Ready for the Big Time," Military & Aerospace Electronics, July 23, 2020, <https://www.military-aerospace.com/home/article/14180250/military-laser-weapons>.
- 100 Shaun Waterman, "Directed Energy Weapons Move Closer to Prime Time," Air Force Magazine, October 29, 2019, <https://www.airforcemag.com/directed-energy-weapons-move-closer-to-prime-time/>.
- 101 Dan Gouré, "Electronic Warfare Is Becoming the Most Lethal Counter Drone Technology," RealClearDefense, September 20, 2019, https://www.realcleardefense.com/articles/2019/09/20/electronic_warfare_is_becoming_the_most_lethal_counter_drone_technology_114755.html.
- 102 Mark Pomerleau, "What DoD's Weapon Tested Said About Army Electronic Warfare," C4ISRNet, February 7, 2020, <https://www.c4isrnet.com/electronic-warfare/2020/02/07/what-dods-weapon-tester-said-about-army-electronic-warfare/>.
- 103 Eric Niiler, "The Pentagon Is Pouring \$328 Million into High-Tech Laser Weapons," Seeker, January 12, 2017, <https://www.seeker.com/the-pentagon-is-pouring-328-billion-into-high-tech-laser-weapons-2189876705.html>.
- 104 C. Todd Lopez, "Shanahan: Next Big War May Be Won or Lost in Space," Defense.gov, April 9, 2019, <https://www.defense.gov/Explore/News/Article/Article/1810100/shanahan-next-big-war-may-be-won-or-lost-in-space/>.
- 105 George Dvorsky, "ISS Ditches 2.9-Ton Pallet of Batteries, Creating Its Most Massive Piece of Space Trash," Gizmodo, March 15, 2021, <https://www.gizmodo.com/iss-ditches-2-9-ton-pallet-of-batteries-creating-its-m-1846476992?rev=1615824133239>.
- 106 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>, p. 107.
- 107 Office of the Secretary of Interior, "Federal Register: Final List of Critical Minerals 2018," Federal Register, May 18, 2018, <https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018>.
- 108 Paul Nash, "China's 'Going Out' Strategy," Diplomatic Courier, May 10, 2012, [https://www.diplomaticcourier.com/posts/china-s-going-out-strategy#:~:text=for%20foreign%20investment.-,The%20government%20encouraged%20companies%20to%20%E2%80%9Cgo%20further%20outwards-%E2%80%9D%20\(Jinyibu,RMB\)%2C%20China's%20currency%2C%20to](https://www.diplomaticcourier.com/posts/china-s-going-out-strategy#:~:text=for%20foreign%20investment.-,The%20government%20encouraged%20companies%20to%20%E2%80%9Cgo%20further%20outwards-%E2%80%9D%20(Jinyibu,RMB)%2C%20China's%20currency%2C%20to).
- 109 Amnesty International, "Is My Phone Powered by Child Labour?", accessed August 6, 2021, <https://www.amnesty.org/en/latest/campaigns/2016/06/drc-cobalt-child-labour/>.
- 110 Jack Farchy and Hayley Warren, "China Has a Secret Weapon in the Race to Dominate Electric Cars," Bloomberg, December 2, 2018, <https://www.bloomberg.com/graphics/2018-china-cobalt/>.
- 111 The White House, "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth: 100-Day Reviews Under Executive Order 14017," whitehouse.gov, June 2021, <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>, p. 167.
- 112 Frik Els, "Chart: China's Stranglehold on Electric Car Battery Supply Chain," Mining.com, April 16, 2020, <https://www.mining.com/chart-chinas-stranglehold-on-electric-car-battery-supply-chain/>.
- 113 Tim De Chant, "The Cobalt Empire," The Wire China, October 18, 2020, <https://www.thewirechina.com/2020/10/18/the-cobalt-empire/>.
- 114 Nicolò Campagnol et al., "Metal Mining Constraints on the Electric Mobility Horizon," McKinsey & Company, April 1, 2018, <https://www.mckinsey.com/industries/oil-and-gas/our-insights/metal-mining-constraints-on-the-electric-mobility-horizon>.
- 115 John Xie, "How China Dominates Global Battery Supply Chain," Voice of America, September 1, 2020, <https://www.voanews.com/silicon-valley-technology/how-china-dominates-global-battery-supply-chain>.
- 116 Securing America's Future Energy, "The Commanding Heights of Global Transportation," September 2020, <https://2uj256f-s8px404p3p2l7nvkd-wpengine.netdna-ssl.com/wp-content/uploads/2020/09/The-Commanding-Heights-of-Global-Transportation.pdf>, p. 7.
- 117 Els, "China's Stranglehold on Electric Car Battery Supply Chain," <https://www.mining.com/chart-chinas-stranglehold-on-electric-car-battery-supply-chain/>.
- 118 US Geological Survey, Mineral Commodity Summaries, January 2020, <https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-lithium.pdf>.

- 119 Sofia Jeremias, "The Rise of Electric Vehicles Is Disrupting Life in a Small Western Community," *Desert News*, April 6, 2021, <https://www.deseret.com/indepth/2021/4/6/22345917/lithium-mines-electric-vehicles-disrupting-life-in-one-small-nevada-community-elon-musk-thacker-pass>.
- 120 US Geological Survey, "Mineral Community Summary 2021," <https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf>.
- 121 Benchmark Mineral Intelligence, "China Is Constructing Graphite Anode Megafactories for the Lithium Ion Battery Surge," October 19, 2017, <https://www.benchmarkminerals.com/china-is-constructing-four-graphite-anode-megafactories-for-the-lithium-ion-battery-surge/>.
- 122 Benchmark Mineral Intelligence.
- 123 US Geological Survey; 100-Day Reviews under Executive Order 14017, p. 159.
- 124 Ibid.
- 125 Benchmark Mineral Intelligence.
- 126 Vivas Kumar, "Lithium-Ion Battery Supply Chain Technology Development and Investment Opportunities," Benchmark Mineral Intelligence, June 2020, <https://www.benchmarkminerals.com/wp-content/uploads/20200608-Vivas-Kumar-Carnegie-Mellon-Battery-Seminar-V1.pdf>.
- 127 Benchmark Mineral Intelligence.
- 128 Ibid.
- 129 Mike Sanders, "Lithium-Ion Battery Material Supply and Demand 2016-2025," Avicenne Energy, June 17, 2017, <http://www.avicenne.com/pdf/Lithium-Ion%20Battery%20Raw%20Material%20Supply%20and%20Demand%202016-2025%20C.%20Pilot%20-%20M.%20Sanders%20Presentation%20at%20AABC-US%20San%20Francisco%20June%202017.pdf>.
- 130 Ibid.
- 131 Benchmark Mineral Intelligence.
- 132 Marian Willuhn, "Zero-Waste Batteries," *Pv Magazine International*, February 10, 2020, <https://www.pv-magazine.com/magazine-archive/zero-waste-batteries/>.
- 133 "Executive Summary: National Blueprint for Lithium Batteries: 2021-2030," June 2021, <https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries>.
- 134 Ibid.
- 135 David Howell, "National Blueprint for Lithium Batteries and 100 Day EO Report on High-Capacity Battery Supply Chains" (presentation, Military Power Sources Committee, virtual event, July 8, 2021), <https://www.forgennano.com/mpsc/lithium-ion-battery-supply-chain-symposium/>.
- 136 Schadlow, "Trading One Dependency for Another," *War on the Rocks*, May 12, 2021, <https://warontherocks.com/2021/05/trading-one-dependency-for-another/>.
- 137 "100-Day Reviews Under Executive Order 14017," p. 92-93, 115-116, 129-131.
- 138 US Congress, Senate, Committee on Armed Services, *Hearing to Receive Testimony on the United States' Strategic Competition with China*, 117th Congress, 1st sess., June 8, 2021, https://www.armed-services.senate.gov/imo/media/doc/21-46_06-08-2021.pdf, p. 59.
- 139 American Automakers, "US Economic Contributions," AAPC, accessed June 29, 2021, <https://www.americanautomakers.org/us-economic-contributions>.
- 140 Kim Hill, Adam Cooper, and Debra Menk, "Contribution of the Automotive Industry to the Economies of all Fifty State and the United States," Center for Automotive Research, April 2010, <https://www.cargroup.org/wp-content/uploads/2017/02/CONTRIBUTION-OF-THE-AUTOMOTIVE-INDUSTRY-TO-THE-ECONOMIES-OF-ALL-FIFTY-STATES-AND-THE-UNITED-STATES.pdf>.
- 141 "NAATBatt 2021 Suggests a Three-Part Plan for Building an Advanced Battery Industry in North America," NAATBatt International, February 12, 2021, <https://naatbatt.org/naatbatt-2021-suggests-a-three-part-plan-for-building-an-advanced-battery-industry-in-north-america/>.
- 142 Ibid.
- 143 Jillian Kay Melchior, "Carrier's Mexico Move Was Entirely Predictable," *National Review*, February 19, 2016, <https://www.nationalreview.com/2016/02/carrier-move-big-government-failure/>.
- 144 Department of Defense, Defense Acquisition Regulations System, "Defense Federal Acquisition Regulation Supplement: Restriction on the Acquisition of Certain Magnets and Tungsten (DFARS Case 2018–D054)," *Federal Register* 84, no. 250, <https://www.govinfo.gov/content/pkg/FR-2019-12-31/pdf/2019-27825.pdf>.
- 145 The White House, 100-Day Report, <https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf>, p. 116.
- 146 Jim Greenberger, "The Challenge of Building a Lithium Battery Supply Chain in North America," NAATBatt International, May 28, 2021, <https://naatbatt.org/the-challenge-of-building-a-lithium-battery-supply-chain-in-north-america/>. The Hamilton Commission would like to thank Mr. Greenberger for kindly agreeing to brief our commissioners.
- 147 US Congress, US-China Economic and Security Commission, "Unfinished Business: Export Control and Foreign Investment Reforms," June 1, 2021, <https://www.uscc.gov/research/unfinished-business-export-control-and-foreign-investment-reforms>.
- 148 US Department of Energy, "Energy Storage Grand Challenge," Energy.gov, accessed September 9, 2021, <https://www.energy.gov>.

gov/energy-storage-grand-challenge/energy-storage-grand-challenge.

- 149 US Department of Energy, Vehicle Technologies Office, “Batteries: 2019 Annual Progress Report,” https://www.energy.gov/sites/default/files/2020/06/f75/VTO_2019_APR_Batteries-FINAL2_-compressed_0.pdf.
- 150 John Wu, “Fact of the Week: Projects Funded by ARPA-E are More Likely To Produce a Patent and Scientific Publication than Projects Funded by Other DOE Programs,” Information Technology & Innovation Foundation, July 23, 2018, <https://itif.org/publications/2018/07/23/fact-week-projects-funded-arpa-e-are-more-likely-produce-patent-and>.
- 151 The White House, “FACT SHEET: The American Jobs Plan,” [whitehouse.gov](https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/), March 31, 2021, <https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/>.
- 152 NAATBatt International, “Three-Part Plan for Building an Advanced Battery Industry in North America,” <https://naatbatt.org/naatbatt-2021-suggests-a-three-part-plan-for-building-an-advanced-battery-industry-in-north-america/>.
- 153 US Department of Defense, Office of the Assistant Secretary of Defense for Energy, Installations, and Environment, *2016 Operational Energy Strategy*, <https://www.acq.osd.mil/eie/OE/OE%20Strategy%20Page.html>.
- 154 Office of the Undersecretary of Defense, “Summary of Defense Production Act Title III Authorities,” NDIA, March 18, 2020, <https://www.ndia.org/-/media/sites/press-media/dpa-title-iii-overview.ashx?la=en>.
- 155 Federal Grants, “Defense Production Act Title III for Lithium Ion Battery Production for Military Applications Project,” [federal-grants.com](https://www.federal-grants.com/Defense-Production-Act-Title-III-for-Lithium-Ion-Battery-Production-for-Military-Applications-Project-60229.html), accessed August 6, 2021, <https://www.federal-grants.com/Defense-Production-Act-Title-III-for-Lithium-Ion-Battery-Production-for-Military-Applications-Project-60229.html>; Department of Defense, Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, “Annual Industrial Capabilities: Annual Report to Congress for 2015,” September 2016, <https://www.businessdefense.gov/Portals/51/Documents/Resources/2015%20AIC%20RTC%2010-03-16%20-%20Public%20Unclassified.pdf?ver=2017-04-18-072624-770>, p. C-11.
- 156 Sam Abuelsamid, “General Motors, LG Chem Form Ultium Cells Battery Joint Venture,” *Forbes*, May 19, 2020, <https://www.forbes.com/sites/samabuelsamid/2020/05/19/general-motors-lg-chem-joint-venture-to-be-called-ultium-cells-llc/>.
- 157 The White House, “US- Japan Joint Leaders’ Statement: ‘US – JAPAN GLOBAL PARTNERSHIP FOR A NEW ERA’,” [whitehouse.gov](https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/16/u-s-japan-joint-leaders-statement-u-s-japan-global-partnership-for-a-new-era/), April 16, 2021, <https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/16/u-s-japan-joint-leaders-statement-u-s-japan-global-partnership-for-a-new-era/>.

Hudson Institute
1201 Pennsylvania Avenue, Fourth Floor, Washington, D.C.
20004
+1.202.974.2400 www.hudson.org