A National Energy Storage Initiative

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Summary

The next administration should establish a national initiative built around ambitious goals to accelerate development and deployment of dramatically improved energy-storage technologies. Developing such technologies would help establish a strategic new domestic manufacturing sector. Deploying such technologies would expand the range of low-carbon pathways available to fight climate change—especially those relying on variable renewable energy resources, like wind and solar power. Deploying such technologies would also improve the performance of smartphones, drones, and other vital electronic tools of the 21st century.

1. Challenge and opportunity

Electricity systems, no matter how big or small, must instantaneously balance supply and demand, generation and load—or suffer blackouts. This imperative has long motivated scientists and technologists to seek the holy grail of affordable, reliable, durable, and safe energy storage. Yet, despite many decades of efforts, batteries remain expensive, fickle, short-lived, and dangerous for many applications. Other forms of energy storage, like thermal and compressed-air storage, suffer from major drawbacks as well.

Radically improved energy-storage technologies would help the nation and the world solve some of their most pressing problems. Most urgently, improved energy storage would expand the range of low-carbon pathways to fight climate change and reduce dependence on fossil fuels by allowing the electricity grid to accommodate higher levels of renewable energy. Improved energy storage would allow electric vehicles (EVs) to better meet drivers' expectations for value and performance, thereby speeding up EV adoption and further helping to address the climate challenge. Better batteries would also let people stop worrying about whether their electronic devices are charged, improving security and strengthening the economy in a world where these and other connected devices are ubiquitous.

Given the importance and magnitude of these opportunities, energy storage has become a critical industry of the future—one that nations around the world seek to capture. China and the European Union, for instance, are making significant strategic investments to build domestic capabilities for development and manufacturing of energy storage technologies.[1,2] These and other international competitors are challenging the U.S. energy innovation ecosystem—our research universities, national laboratories, start-

[1] China Energy Storage Alliance, "Energy Storage Emphasized in China's Latest Industry Plan", October 9, 2016, http://en.cnesa.org/latest-news/2016/10/9/a823ur3r41ob5n2tv2x5l0ai4wneqf.

[2] Ben Hall and Richard Milne, "Europe First: How Brussels Is Retooling Industrial Policy," *Financial Times*, December 2, 2019, https://www.ft.com/content/140e560e-0ba0-11ea-bb52-34c8d9dc6d84?shareType=nongift.

up companies, and established technology firms to invent, commercialize, and scale-up next-generation energy-storage technologies.

1.1 Opportunities by sector

Electric power

The rapidly dropping cost of wind and solar power has opened major pathways to decarbonize electricity systems. But these power generation technologies are variable: that is, their output fluctuates by the hour, day, and season. As the renewable share of generation rises on a grid, such fluctuations make balancing supply and demand increasingly difficult, threatening brownouts and blackouts. Grid-scale energy storage has the potential to address this challenge. Although one energy-storage technology (lithium-ion batteries) has been improved to the point that it has begun to make a significant impact on the grid, major gaps remain. Fully solving the grid-storage problem requires technologies that are much cheaper and last much longer than current systems. Grid-storage technologies must be able to hold enough electricity to power a grid for a week or more at a cost of just a few cents per kilowatt-hour (kWh), while operating only a few times each year.[3]

Transportation

Lithium-ion batteries are also kick-starting the electrification of transportation. Their declining cost is one of the key factors helping to bring EVs into the mainstream. EVs are cleaner than gasoline-powered cars if they are charged on low-carbon electricity grids. EVs are also easier to maintain and cheaper to operate. However, the ultimate triumph of EVs in the auto market is far from assured. Batteries that are safer, rely on more abundant materials, allow vehicles to go 500 miles or more on a charge, last for at least a decade, and are easily recharged and recycled would make the success of EVs more likely, with huge payoffs for the global climate.[4]

Electronics

The suite of technologies sometimes lumped together as the "fourth industrial revolution" is another broad domain that would benefit from advances in energy storage.[5] Robots, drones, sensors, and smartphones—and the systems by which they process and exchange information—have become essential tools in modern society.

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[3] David M. Hart, "Making "Beyond Lithium" a Reality: Fostering Innovation in Long-Duration Grid Storage", Information Technology and Innovation Foundation, November 28, 2018, https://itif.org/publications/2018/11/28/making-beyond-lithium-reality-fostering-innovation-long-duration-grid.

[4] International Energy Agency, *Global EV Outlook 2019* (May 2019).

[5] World Economic Forum, *Fourth Industrial Revolution*, https://www.weforum.org/focus/fourth-industrial-revolution.

Most of these electronics are more useful when they can operate without having to maintain a constant connection to the grid. Although batteries are becoming lighter and more efficient, the demands being placed on them are also rising, straining the limits of lithium-ion technology. An order-of-magnitude leap in the energy density of batteries—the amount of electricity stored in a given mass or volume—would unlock a diverse array of valuable new applications for a wide range of electronic devices. For instance, drones, whether they are being used by combat forces, farmers, or utility crews, would be able to stay aloft for days and carry more sophisticated payloads, such as weapons or sensors.

Domestic manufacturing

Paradigm-shifting improvements in energy storage technologies would also create opportunities to build domestic manufacturing capacity in a growing industry of the future. The supply chain for making lithium-ion batteries migrated to East Asia years ago. The largest battery factory for EVs in the United States, Tesla's "giga-factory" in Reno, NV, is run by a joint venture with the Japanese-headquartered firm Panasonic. Tesla has been unable to fully master the finicky methods used to make battery cells.[6] Other U.S.-based EV assembly plants rely on Asian-headquartered battery contractors as well.

Nonetheless, the United States continues to generate new energy storage technologies, including some that could supplant the current generation of lithium-ion batteries. For example, Sila Nanotechnologies, founded in 2011 and based in the San Francisco Bay Area, raised $215 million in 2019 to scale up its manufacturing activity. A half-dozen other U.S.-based battery start-ups have also raised large funding rounds in the past year. Investors include not only venture-capital firms, but also big companies based in Europe and Asia as well as North America. It remains to be seen where the battery supply chain of the future will be located.

2. Proposed action

The next administration, building on the Department of Energy's (DOE) recently announced "Energy Storage Grand Challenge,"[7] should establish a National Energy Storage Initiative (NESI) built around ambitious goals to accelerate development and deployment of dramatically improved energy-storage technologies. These goals should include widespread adoption of:

- Grid-scale systems that can provide at least 500 megawatts (MW) of power for a week at a cost of three cents per kWh or less.

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[6] Lora Kolodny, "Tesla Has a Secret Lab", CNBC, June 26, 2019, https://www.cnbc.com/2019/06/26/tesla-secret-lab-building-battery-cells-to-reduce-panasonic-dependency.html.

[7] DOE, "Energy Storage Grand Challenge", January 8, 2020, https://www.energy.gov/energy-storage-grand-challenge/energy-storage-grand-challenge.

- Vehicle-scale energy-storage systems with performance, safety, and cost characteristics as good as or better than internal-combustion systems (including lifespan and recharging speed).
- Batteries for small devices exhibiting energy density an order of magnitude greater than current lithium-ion batteries.

The NESI should also seek to achieve economic and international goals such as:

- A positive international trade balance in energy-storage technologies and components.
- Global adoption of energy-storage technologies invented and commercialized in the United States across major application domains.

The NESI will require deep collaboration among key federal agencies and with the private sector, academia, and states and localities. This initiative would galvanize the still-thriving energy-storage science and technology community in the United States, spurring the development of better energy-storage technologies and ensuring that the next generation of storage devices are built here.

The case for the NESI is two-fold. First, expanded research, development, and demonstration (RD&D) funding is needed to address market failures in the energy-storage domain. Expanded funding would enable scientific and mission agencies to pursue a diverse array of promising opportunities that have gone un- or underexplored. The result would be new energy-storage materials and concepts, breaking through barriers that have limited current technologies. Second, federal resources and leadership—as well as deep engagement with the private industrial and financial sectors and with key states and localities—are crucial for domestic scale-up and manufacturing made possible by this expanded RD&D portfolio. International competition surrounding energy storage is already fierce. China, in particular, has made no secret of its plan to dominate the global battery and EV industries.[8] The United States must assert leadership on energy storage or risk being left behind.

3. Implementation

The NESI should include four key components: (1) White House leadership and coordination, (2) a federal RD&D budget commitment, (3) increased agency participation and use of an array of policy tools, and (4) mobilization of non-federal actors to undertake aligned actions.

[8] Max J. Zenglein and Anna Holzmann, "Evolving Made in China 2025", Mercator Institute for China Studies, working paper no. 8, July 2019, https://www.merics.org/sites/default/files/2019-07/MPOC_8_MadeinChina_2025_final_3.pdf.

White House leadership and coordination

An Executive Order (EO) from the White House, implemented by the Office of Science and Technology Policy (OSTP) and the National Science and Technology Council (NSTC), would be the foundational action to launch the NESI. White House leadership and attention would catalyze implementing agencies to identify lead units and staff members for the interagency initiative and to undertake internal coordination among their component units (*e.g.*, the science and applied energy offices within DOE). OSTP, NSTC, and agency staff would spearhead the initiative, driving its progress throughout the executive branch and mobilizing support in Congress, industry, science, and the public.

Budget

Delivering on the aforementioned goals would require, at a minimum, tripling current spending on energy storage RD&D programs over five years. The most comprehensive estimate of federal RD&D spending on energy storage comes from a 2015 OMB interagency "crosscut": $300 million.[9] Increasing spending to $900 million or more per year would allow participating agencies to take the following actions:

- Accelerate fundamental research on promising energy-storage materials and systems.
- Create and expand centers of excellence in RD&D on energy storage at universities and government laboratories.
- Build academic-government-industry partnerships to create energy-storage prototypes and pilot projects.
- Conduct large-scale energy-storage demonstration projects in collaboration with end users, such as urban and rural electricity systems and military bases.
- Establish regional manufacturing innovation centers that facilitate technology development, worker training, and small- and medium-enterprise (SME) engagement related to energy storage.

Increased agency participation and use of other policy tools

In addition to DOE, the Departments of Agriculture (USDA), Commerce (DOC), Defense (DOD), Health and Human Services (HHS), Housing and Urban Development (HUD), and Transportation (DOT) as well as the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) should be mobilized to accelerate

[9] Office of Management and Budget, *Government-Wide Funding for Clean Energy Technology* (June 2015). An administration official recently stated that DOE's energy storage R&D spending was $400 million per year. *See* Ben Geman, "DOE Looks To Unlock Energy Storage Advances", *Axios*, January 8, 2020, https://www.axios.com/doe-looks-to-unlock-energy-storage-advances-a7c11194-3560-413b-a971-c36a5c1dcd68.html.

innovation in energy storage. DOC,[10] DOD, HHS,[11] and NSF should collaborate with DOE in expanding the energy storage RD&D enterprise. The other agencies, along with DOE and DOD, should use policy tools such as procurement, regulation, and investment support (*e.g.*, loan guarantees) to help "pull" nascent energy-storage technologies into markets and to assist in establishing domestic production capacity. Tax incentives, legislated by Congress and administered by executive agencies, may also be helpful to accelerate market growth and drive down costs for particular technologies.

Mobilization of non-federal actors

Academia and industry are critical to the success of energy-storage RD&D, manufacturing, and adoption. The vast scope of energy-storage applications amplifies the importance of engaging with a wide variety of end-user industries—especially power-system vendors, utilities, electronics manufacturers, and automakers—as well as producers of storage technology. States and localities, many of which have announced ambitious goals for grid-scale storage, should also be incorporated into the NESI.[12] A few states could house federally supported manufacturing and innovation "clusters" for energy-storage solutions. All states could accelerate adoption of improved energy-storage technologies by fostering receptive markets: for instance, by reforming electricity regulation.

4. Precedents

This proposal builds on two types of historical precedents: (1) broad interagency initiatives in technology areas of national importance, and (2) specific efforts to accelerate innovation in energy-storage technology. The proposal also responds to global competitive threats and capitalizes on opportunities for international cooperation.

The proposed NESI is similar to successful efforts such as the Clinton administration's nanotechnology initiative and the Obama administration's advanced manufacturing initiative.[13] Such initiatives mobilize and coordinate multiple agencies in pursuit of technological capabilities that will contribute significantly to a set of broadly agreed national goals. Success depends on strong presidential commitment at the start and cultivation of stakeholders across partisan, regional, and sectoral lines over time. Effective technology initiatives have major on-the-ground impacts and ultimately

[10] Especially the National Institute of Standards and Technology (NIST).
[11] Especially the National Institutes of Health (NIH).
[12] Julian Spector, "Northeastern States Primed to Be the Next Major Energy Storage Market," *Greentech Media*, July 23, 2019, https://www.greentechmedia.com/articles/read/northeastern-states-are-primed-to-be-the-next-major-energy-storage-market.
[13] U.S. Nanotechnology Initiative, "About the NNI," https://www.nano.gov/about-nni ; National Economic Council, "Revitalizing American Manufacturing," October 2016, https://www.whitehouse.gov/sites/whitehouse.gov/files/images/NEC_Manufacturing_Report_October_2016.pdf

become self-sustaining. Two keys to success are (1) White House leadership and attention to foster interagency cooperation, and (2) increased agency budgets to limit resistance from incumbent programs.

Federal funding for energy-storage science and technology has a long track record, particularly with regard to basic research. The American Recovery and Reinvestment Act (ARRA) expanded federal energy-storage funding considerably in the 2010s. ARRA funding supported establishment of the Advanced Research Projects Agency—Energy (ARPA-E), which has become a major source of funding for applied research and prototype development in energy storage. ARRA funding also supported the Joint Center for Energy Storage Research (JCESR) at Argonne National Laboratory; a collaborative demonstration program within DOE's Office of Electricity that worked with utilities, states, and local governments; and loan guarantees for battery manufacturing and grid-scale storage projects.

Many of these investments have paid off handsomely. For instance, an evaluation by the National Academies found that ARPA-E's funding of energy-storage technology has been "highly productive with respect to accelerating commercialization" and led to the formation of at least six new companies in the field.[14] JCESR was renewed for an additional five years in 2018. However, the demonstration and manufacturing elements of the ARRA-funded push were not sustained, primarily due to ideological objections by the Congressional majority that came in after the 2010 midterm elections.[15]

The Department of Energy announced an Energy Storage Grand Challenge on January 8, 2020. This initiative is a welcome step toward the broader initiative outlined in this paper. It seeks ambitious advances in technology, rapid commercialization, and the creation of a domestic manufacturing supply chain. But it does not extend beyond DOE, and whether it will be implemented with the appropriate resources and presidential support is uncertain.[16]

5. International context

Many countries have made energy storage a priority. The European Union has embarked on a multi-billion-dollar battery initiative that led to the establishment of Northvolt, a European-owned battery cell manufacturing start-up. Volkswagen bought 20% of

[14] National Academies of Science, Energy, and Medicine, *An Assessment of ARPA-E* (2017).

[15] Stephen Ezell, David M. Hart, and Robert D. Atkinson, "Bad Blueprint: Why Trump Should Ignore the Heritage Plan to Gut Federal Investment", Information Technology and Innovation Foundation, February 27, 2017, https://itif.org/publications/2017/02/27/bad-blueprint-why-trump-should-ignore-heritage-plan-gut-federal-investment.

[16] DOE, "Energy Storage Grand Challenge" Geman, "DOE Looks to Unlock"; David M. Hart, "Energy Storage RD&D in the Fiscal Year 2020 Budget Proposal," Information Technology and Innovation Foundation, March 27, 2019, https://itif.org/publications/2019/03/27/energy-storage-rdd-fiscal-year-2020-budget-proposal.

Northvolt and is working with it to build a second cell factory. Energy storage and EVs are among the sectors targeted by China in its Made in China 2025 program. Massive subsidies from all levels of the Chinese government have flowed through a variety of channels to energy storage projects and companies to fulfill this program, helping China become the world's largest EV market (with more than 50% market share). Korea, Japan, and India are among the other countries undertaking national energy storage initiatives.[17–19]

Although the global race to advance energy-storage technology is intense, the United States possesses many strengths that would allow a domestic energy-storage effort to succeed. These strengths include outstanding research capabilities at universities and national laboratories, a vibrant start-up ecosystem, and a strong industrial sector. The NESI would provide the leadership, funding, and coordination needed to realize the full potential of these assets. It is also important for the United States to foster international cooperation around science underlying energy-storage technology. Scientific knowledge is a global public good that will be under-provided without the leadership of the world's top scientific nation.

6. Stakeholder support

The NESI has a wide range of potential champions and advocates on both sides of the aisle. Congressional Republicans have expressed their support for energy storage through expanded RD&D funding and more ambitious authorizations. The administration's new grand challenge taps into this legislative support. Environmental advocates on the left of the political spectrum are also supportive, perceiving limited energy storage as the biggest technological barrier to expanded deployment of renewables. Similar enthusiasm may be expected from the research community and investors, as well as from states seeking to build a domestic energy-storage industry. These interests have been frustrated by the "invent here, produce there" outcomes of past breakthroughs, such as lithium-ion batteries.

Technology end users may be less enthusiastic or indifferent. Low prices in the short term may be more important to them than innovation in the long run. They may also see the location and ownership of production facilities as irrelevant or argue that the current global division of labor, in which Asian factories built with cheap public-investment

[17] China Energy Storage Alliance, "Energy Storage Emphasized"; Prime Minister's Office (India), "Cabinet Approves National Mission on Transformative Mobility and Battery Storage," March 7, 2019, https://www.pmindia.gov.in/en/news_updates/cabinet-approves-national-mission-on-transformative-mobility-and-battery-storage/.
[18] Hall and Milne, "Europe First".
[19] Asia-Pacific Economic Corporation, "Research on Energy Storage Technologies to Build Sustainable Energy Systems in the APEC Region" (August 2017), https://www.apec.org/Publications/2017/08/Research-on-Energy-Storage-Technologies-to-Build-Sustainable-Energy-Systems-in-the-APEC-Region.

capital supply U.S. needs, is favorable for the United States. Other skeptics may argue that when it comes to supporting expanded deployment of renewables, investing in demand response, larger grids, or other forms of low-carbon electricity generation, such as nuclear power or natural gas plants with carbon capture systems, are better options than energy storage.

7. Goals and metrics

The overarching (*e.g.*, within 10 years) goal of NESI is to make the United States a major center for energy storage innovation and production.

One essential short-term step towards achieving this goal is establishing key organizational components of the NESI, such as an interagency working group and a mechanism to engage with non-federal stakeholders, including industry, academia, and states. A second critical step is expanding budgets for relevant federal agencies to put them on a pathway to triple federal funding for energy-storage RD&D.

In the medium term, metrics such as growth in scientific publications and patents, formation of new energy-storage companies, equity and project investment, product introduction, and manufacturing-cost reduction will provide insights on progress.

In the long term, success of the NESI should be assessed by the level of market penetration of new energy-storage storage products across application domains including electric power, transportation, and electronics in the context of a growing overall storage market. Success of the NESI should also be assessed through consideration of the international trade balance related to energy storage and adoption of U.S.-developed energy-storage technologies.

8. Proposed initial steps

The next president should sign an EO establishing the NESI and directing the White House Office of Science and Technology Policy to convene a federal interagency task force. The task force should prepare a strategic plan and develop a budget for the initiative in consultation with key stakeholders. The plan should identify technological needs and opportunities and set specific objectives, taking into account global competition and cooperation with respect to energy storage. Congress should support the NESI by appropriating funding needed to implement the strategic plan, and by providing additional authorization as required.

Implementing agencies should pursue energy-storage RD&D as it relates to their respective missions, while collaborating to manage overlaps and avoid gaps. RD&D

activities should strengthen the intramural and extramural research and industrial communities. As innovative storage technologies reach maturity, DOC, DOD, and DOE should work with states and regional economic-development agencies to foster markets and develop manufacturing capabilities. Congress should provide tax incentives that help to pull these technologies into the market, thereby driving down cost and expanding deployment.

9. Conclusion

Energy-storage technologies in widespread use today are not good enough to meet fundamental 21st-century challenges, including climate change, economic growth, and international security. A national initiative to accelerate domestic development and deployment of dramatically improved energy-storage technologies would position the United States to lead the world in addressing these challenges while building its economy. Although global competition in energy storage is fierce, our nation has strong capabilities that—if used strategically—position the United States to catch up with and ultimately surpass its rivals in this vital emerging industry. The NESI provides a pathway for the next president to translate this vision into reality.

About the author

David M. Hart is Professor at the Schar School of Policy and Government at George Mason University and senior fellow at the Information Technology and Innovation Foundation (ITIF). David's research focuses on clean energy innovation policy. His recent work for ITIF includes "Less Certain than Death: Using Tax Incentives to Drive Clean Energy Innovation" (December 2019); "The Global Energy Innovation Index: National Contributions to the Global Clean Energy Innovation System" (August 2019); "Making "Beyond Lithium" a Reality: Fostering Innovation in Long-Duration Grid Storage" (November 2018); and "Beyond the Pork Barrel: An Assessment of the Obama Administration's Energy Demonstration Projects (which was published in *Energy Policy* in August 2018). He co-authored the April 2018 MIT Energy Innovation working paper "Energy Storage for the Grid: Policy Options for Sustaining Innovation" with William B. Bonvillian, and Unlocking Energy Innovation (MIT Press, 2012) with Richard K. Lester. David served as senior associate dean of the Schar School from 2013 to 2015 and as assistant director for innovation policy at the White House Office of Science and Technology Policy (OSTP) from 2011 to 2012. He co-chairs the Innovation Policy Forum at the National Academies of Science, Engineering and Medicine.

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