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Energy Storage Roadmap for Northern Appalachia 2022

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Executive Summary

Background

In 2020, BRITE Energy Innovators commissioned the development of an industry "roadmap" to guide stakeholders in Northern Appalachia to foster the growth of its energy storage industry. Northern Appalachia is a region that has long been associated with energy and natural resources, especially for coal and natural gas. It is evolving rapidly in response to changes the United States and the world have seen in the energy and manufacturing sectors. Meanwhile, energy storage is opening the door to new opportunities for the region: energy storage technologies will fundamentally transform how energy is generated and delivered. Northern Appalachia has the assets to play a key role in in this transition. Indeed, Northern Appalachia has already begun to do so.

This report follows a roadmap developed by Cleveland State in 2019 on behalf of TeamNEO, a Northeast Ohio economic development organization. TeamNEO thereafter turned the execution of the roadmap over to BRITE Energy Innovators, a regional energy technology incubator located in Warren, Ohio serving Northeast Ohio, Western Pennsylvania and other parts of Northern Appalachia. However, the assets that made Northeast Ohio a growing energy storage cluster do not end at the Ohio border. Indeed, Northern Appalachia as a region has long enjoyed a strong legacy as an energy hub. Accordingly, BRITE commissioned Cleveland State to expand the 2019 TeamNEO study to include all of Northern Appalachia, and to update the roadmap in light of more recent U.S. Department of Energy planning. Northern Appalachia is better understood to be an archipelago of related clusters, ranging from Northeast Ohio to Western and Central Pennsylvania, and into West Virginia.

To better understand the region's asset base, the Study Team examined various industry databases to identify businesses and institutions located in the 139 counties identified by the Appalachian Regional Commission as belonging within Northern Appalachia.[1] This included 32 counties located in Ohio, 52 in Pennsylvania, and 55 in West Virginia. Northern Appalachian Counties comprised about 17% of Ohio's population, 45% of Pennsylvania's, and all of West Virginia's.[2] Because it was included in the 2019 TeamNEO report, Cleveland and Akron/Canton were not included in this Study.

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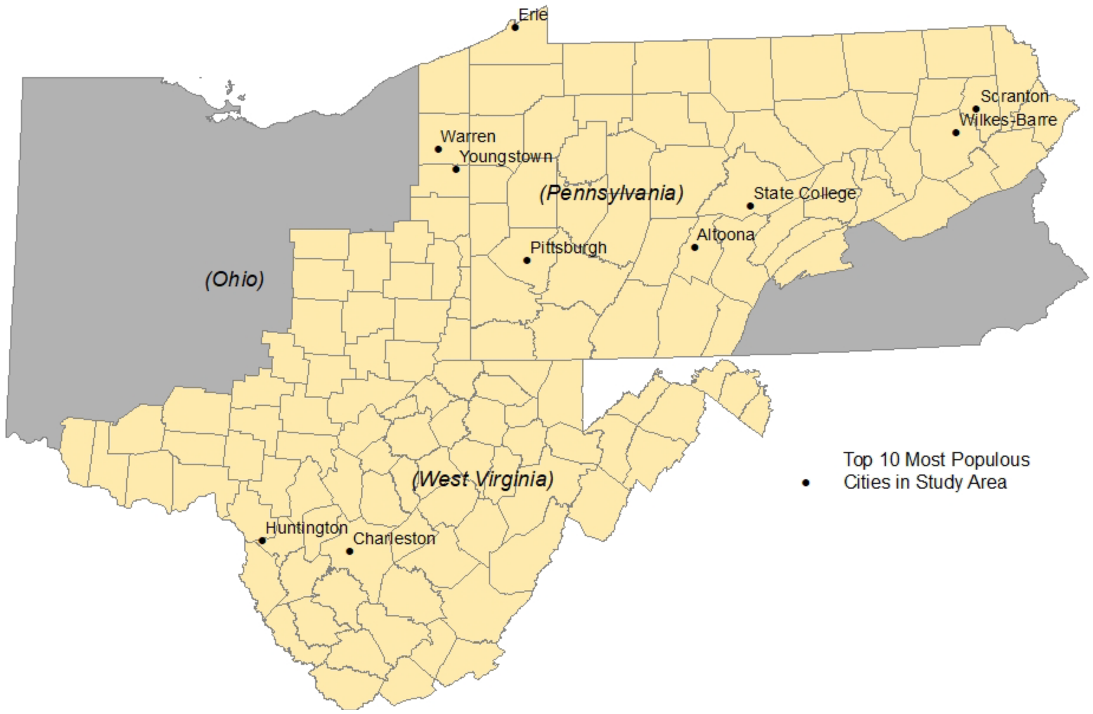
[1] The Appalachian Regional Commission (ARC) is an economic development partnership agency of the federal government and 13 state governments focusing on 423 counties across the Appalachian Region. Established by Congress in 1965, the ARC has invested with local, regional, and state partners to transform Appalachian communities, create jobs, and strengthen the regional economy. *See* https://www.arc.gov.

[2] https://www.arc.gov/wp-content/uploads/2021/06/PRB_ARC_Chartbook_ACS_2015-2019_FINAL_2021-06_R1.pdf#page=14

Figure 1. Appalachian Counties in Ohio, Pennsylvania, and West Virginia



Source: Study Team

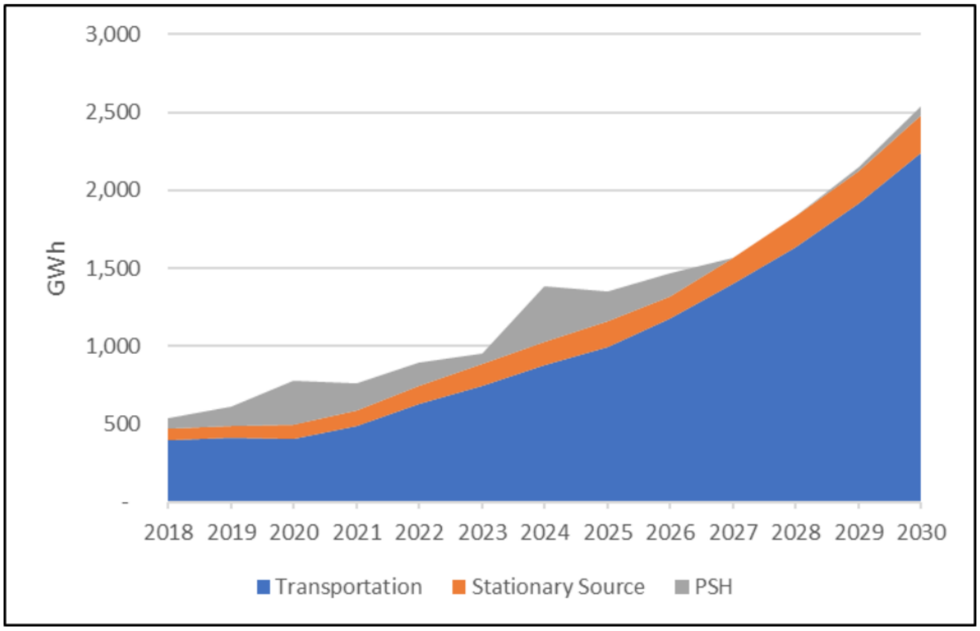
This energy storage roadmap for Northern Appalachia analyzes the trends driving growth for energy storage applications in the grid and transportation sectors. The report also highlights commercial and structural assets within Northern Appalachia that will help enable the region to play a part in the growing global energy storage industry. New innovations and technologies will open doors for the Northern Appalachian energy storage industry to enter.

This roadmap describes energy storage technologies and how the Northern Appalachian energy storage industry uses them. It also provides recommendations for policymakers interested in growing the energy storage industry in Northern Appalachia. The goal of this roadmap is to explain how stakeholders can combine regional assets with well-designed policies to grow the energy storage industry in Northern Appalachia.

Energy Storage Global Market

The DOE projects the global energy storage market to reach 2,500 gigawatt hours per year by 2030. While consumer electronics drove much of the energy storage industry in the 2010s, the DOE now projects transportation applications, pushed by electric vehicle adoption, will drive energy storage industry growth in the 2020s. The DOE also projects stationary storage applications to grow in the upcoming decade, although less aggressively than for transportation applications. The DOE also projects pumped hydro storage growth in the early 2020s—for which Northern Appalachia has the right geography—but little new growth beyond 2027.

Figure 2. DOE Projected Energy Storage Consumption Per Year Through 2030



Source: DOE

Northern Appalachian Assets

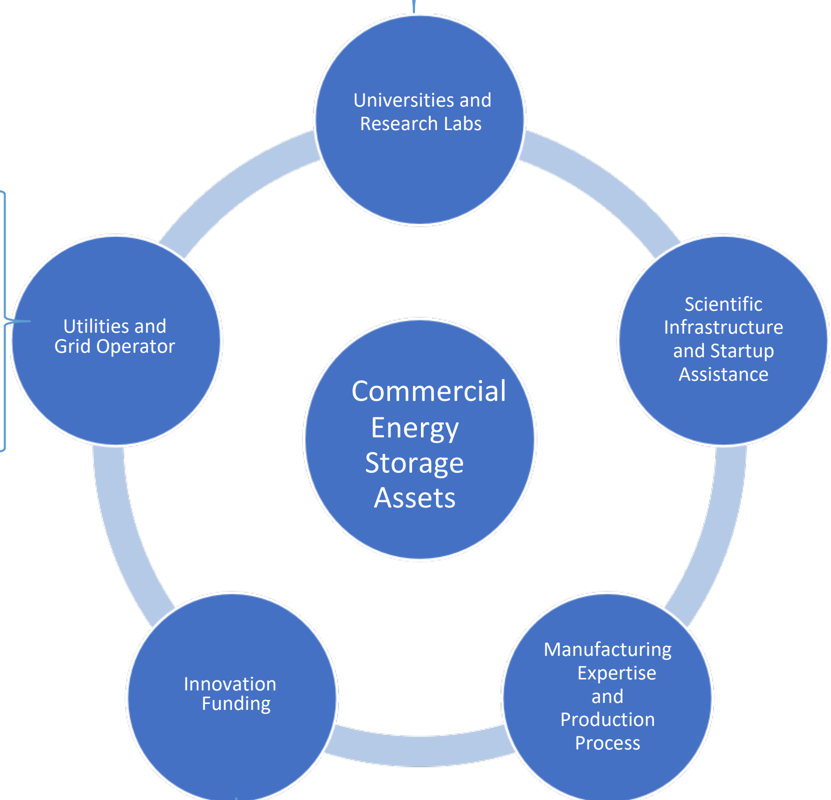
Northern Appalachia has a collection of research, startup infrastructure, production process, innovation funding, and utility resources to support the growth of its energy storage industry. Based on the Study Team's research of Northern Appalachian commercial enterprises engaged in the business of energy storage, at least 17,000 workers are employed across over 200 companies.

The Study Team identified commercial assets by assembling a list of businesses and institutions in Northern Appalachia in the energy storage or related industries. The team compiled this list from third-party company databases including D&B Hoovers, Mergent Intellect, Reference USA, and the Thomas Register of American Manufacturers.

The following diagram depicts the available assets currently available within Northern Appalachia, which assets can or already form energy storage clusters. The 200-plus commercial enterprises are at the center of the diagram, and are supported by an array of public and private institutions, including universities, utilities, laboratories, incubators, early-stage investors and economic development organizations.

Figure 3. Structural Assets in Northern Appalachia

- Carnegie Mellon University
- Marshall University
- National Energy Technology Laboratory
- Ohio University
- Penn State University
- University of Pittsburgh
- Touchstone Research Laboratory
- West Virginia University
- Youngstown State University



- AEP Ohio
- Appalachian Power Company
- Duquesne Light Company
- Mon Power
- Penelec
- Penn Power
- West Penn Power
- Touchstone Energy (electric co-ops)
- American Public Power Association (municipal utilities)

- Appalachian Center for Economic Networks
- Ben Franklin Technology Partners
- BRITE Energy Partners
- Idea Foundry
- Innovation Works
- TekRidge Center
- Ten50
- Tri County Business Dev. Center
- West Virginia Hive Network

- Draper Triangle
- JobsOhio R&D Center Grant
- Mountain State Capital
- Mountaineer Capital L.P.
- Novitas Capital
- Smithfield Trust
- Valley Growth Ventures
- Vantage Ventures

- Alcoa
- Ohio Southeast Economic Development
- PPG Industries
- WV/Ohio/PA Manufacturers Associations
- WV Manufacturing Extension Partnership/MAGNET

Human resources are also important to the energy storage industry in Northern Appalachia. The region has multiple metropolitan areas with concentrated specialization in engineering fields core to the energy storage industry. The table below compares identifies Northern Appalachian *location quotients* for key engineering fields for the energy storage industry.[3]

Table 1. Concentrated Engineering Fields in Northern Appalachian Metropolitan Areas

Metropolitan Area	Engineering Field	Location Quotient
Charleston, WV	Chemical	2.38
Erie, PA	Materials	4.12
	Mechanical	1.68
Pittsburgh, PA	Electrical	1.33
	Materials	1.26
	Mechanical	1.62
State College, PA	Electrical	1.29
Youngstown, OH	Materials	3.77

Source: Bureau of Labor Statistics

Cost of living is also modest in Northern Appalachia compared to other energy storage clusters across the country. The table below compares the cost of living in Northern Appalachian metropolitan areas to that for other areas that are considered energy storage hubs. (The cost of living for these regions relative to the national average is listed from low to high, with Northern Appalachian regions highlighted in yellow). Northern Appalachia's low cost of living and concentration of engineering assets in the region make it a strong candidate for energy storage innovation and manufacturing clusters in the future.

[3] A location quotient represents specialization in an occupation compared to a national average of 1, so a region with a location quotient of 2.5 would have 2.5 times more concentration in that occupation than the national average. A location quotient of 1.2 or higher is considered "concentrated."

Table 2. Cost of Living in Northern Appalachian Counties

Area Name	Price of Goods, Services and Housing Compared to National Average
Youngstown, OH	14.9% lower
Huntington, WV	14.4% lower
Charleston, WV	14% lower
Morgantown, WV	10.2% lower
Erie, PA	8.7% lower
Scranton, PA	8.5% lower
Grand Rapids, MI	8% lower
Williamsport, PA	8% lower
Pittsburgh, PA	7.6% lower
Charlotte, NC	5.6% lower
Detroit, MI	4.7% lower
Reno, NV	1.6% lower
State College, PA	Equal
San Francisco, CA	34.5% higher

Source: Bureau of Economic Analysis

Taking Stock of Northern Appalachia's Energy Storage Industry

Below is a summary of the strengths, weaknesses, opportunities, and threats to the Northern Appalachian energy storage industry.

Table 3. SWOT Analysis of Northern Appalachian Energy Storage Industry

Strengths	Weaknesses
• Strong research institutions, energy legacy • Proximity to consumers • Concentration of engineering profession • Concentration of manufacturing industry • Low cost of living	• Public policy support • Low adoption rate for renewables • Low energy costs making energy that requires storage less economically feasible[4] • Perception that region is tied to 20^{th} century grid, energy models
Opportunities	**Threats**
• Growing global market • Venture capitalists eager to support regional innovation • Proximity to manufacturing assets	• National and global competition • Regulatory uncertainty • Stronger technology adoption on West and East Coasts

Source: Study Team

[4] Low energy costs would normally be considered a strength for manufacturing clusters rather than a weakness. However low power costs hinder local adoption – it can make it difficult to recoup costs when the purpose of energy storage is supplying power to the grid. High power costs are a significant driver for energy storage clusters in California, for instance.

The DOE projects the transportation sector will be the main driver of growth of the energy storage industry over the next decade. Consumer demand, public policy, declining battery prices, and vehicle performance are all driving growth for this segment of the energy storage market. Northern Appalachia's strength as a manufacturing hub can help position the region as a leader in manufacturing for transportation-related energy storage in the near future.

Northern Appalachia has strong assets focused on manufacturing and process improvement that include companies, associations, economic development organizations, university centers, and public/private partnerships. This ecosystem of public and private organizations is capable of galvanizing innovation and expansion for the region's energy storage industry, helping to drive national competitiveness within the global market for this sector.

Recommendations for Energy Storage Cluster Development

1. Promote grid and stationary storage in Northern Appalachia

- Adopt procurement mandates for energy storage at the utility level.
- Implement financial incentives (e.g., subsidies, tax credits) for deploying energy storage.
- Develop comprehensive regulatory framework for energy storage, specifying the conditions under which utilities may own and operate distributed storage.
- Include energy storage in utility integrated resource plans.
- Allow energy storage paired with distributed generation to qualify for net metering.
- Maintain or expand existing renewable portfolio standards.
- Ensure regulatory framework is flexible enough to allow for microgrids, smart grids, and complex, multiple-end user applications of energy storage.
- Develop a comprehensive, reliable cost-benefit analysis tool for energy storage that accurately assess the viability of investments and their effect on grid operations.
- Require utilities to file distribution resource plan proposals that identify optimal locations for the deployment of distributed resources such as energy storage.
- Modernize interconnection standards to better reflect the operating characteristics of energy storage.

2. Promote adoption of energy storage in the transportation sector

- Adopt sales requirements for zero-emission vehicles.
- Adopt or strengthen fuel economy standards.
- Incentivize purchase of vehicles that use energy storage technology.
- Develop standards and regulations for vehicle charging equipment and attached buildings.
- Incentivize implementation of charging equipment and supporting infrastructure.
- Develop regulations to enable vehicle-to-grid interface and power flow.

3. Fund Market Validation Program for Energy Storage Startups

One of the biggest obstacles that entrepreneurs face as they bring new technology to market is the "Technological Valley of Death." This is the stage where entrepreneurs must demonstrate the market validity of their technologies to prove to investors that they are viable beyond the laboratory. To help startups get off the ground, incubators and accelerators offer services such as support with developing a business plan, one-on-one mentoring, access to testing equipment, investor connections, and funding for prototype development.

What energy-related startups are missing, however, is a formal market validation program to determine the actual need for their product within a target market. This process for validating the business plan of startups demonstrates to investors that sufficient demand exists for new energy storage technologies to warrant continued funding, increasing the likelihood of successful commercialization.

Key Takeaways from Study

1. Northern Appalachia has assets that make it suitable for energy story cluster development, including the following:

   - A high concentration of human capital in the fields of chemical, electrical, materials, and mechanical engineering.
   - A low cost of living compared to competitor metropolitan areas.
   - Over 200 commercial businesses with capacity to be involved in a regional energy storage industry.
   - Laboratories, incubators, universities and early stage funding organizations that can be important to new technology development.

2. Northern Appalachia's history of manufacturing and legacy commercial and structural assets position it well to be a part of a growing energy storage industry, including the rapidly growing transportation sector.

3. Northern Appalachia's research institutions can drive cluster development for energy storage. The region is home to many research institutions and universities, as well as laboratories and incubators that can also drive cluster development.

4. Stakeholders in the region have a range of tools for encouraging the energy storage industry. These range from angel and public investment into technologies to public policy options that encourage grid and transportation-sector growth.

1. Introduction

The Energy Policy Center at Cleveland State University, through BRITE Energy Innovations (together, the “Study Team”), has undertaken this study to evaluate the status of energy storage technology development in the Northern Appalachian region of Ohio, Pennsylvania, and West Virginia. The Study Team has further analyzed opportunities for the region to identify and capture markets, and has made recommendations for regional cluster development.

This report follows a roadmap developed by Cleveland State in 2019 on behalf of TeamNEO, a Northeast Ohio economic development organization. TeamNEO thereafter turned the execution of the roadmap over to BRITE Energy Innovators, a regional energy technology incubator located in Warren, Ohio serving Northeast Ohio, Western Pennsylvania and other parts of Northern Appalachia. However, the assets that made Northeast Ohio a growing energy storage cluster do not end at the Ohio border. Indeed, Northern Appalachia has enjoyed a strong legacy as an energy hub. Accordingly, BRITE commissioned Cleveland State to expand the 2019 TeamNEO study to include all of Northern Appalachia, and to update the roadmap in light of more recent U.S. Department of Energy planning.

Northern Appalachia comprises 139 counties within Ohio, Pennsylvania, and West Virginia, ranging from the eastern suburbs of Cincinnati in the west to the Delaware River in the east, and from the Virginia border in the south to Lake Erie in the north. Counties were deemed “Appalachian” based upon their designation as such by the Appalachian Regional Commission.[5] This region has long been a center for coal production, which has powered the regional economy for over 100 years. In recent years, coal production has diminished, in part due to competition from natural gas, and in part due to worldwide efforts to reduce carbon emission. This has led economic development thought leaders to identify strategies for energy diversification for the region, including the adoption of significant amounts of renewable energy.[6]

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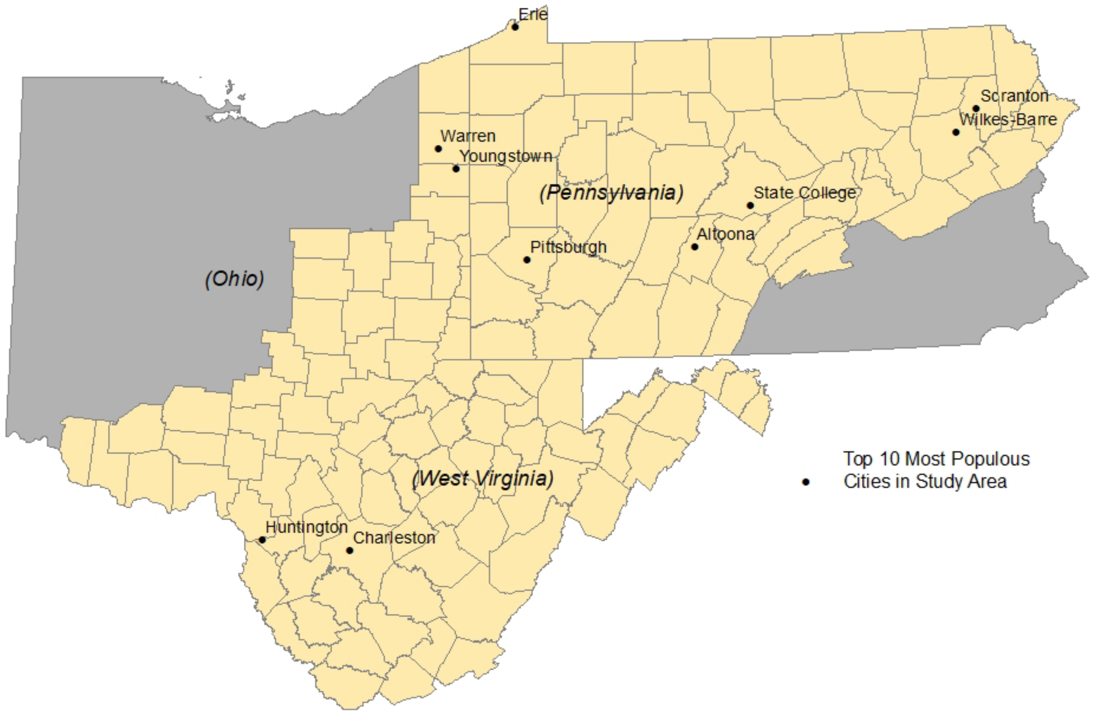
[5] https://www.arc.gov

[6] McIlmoil, Rory, and Evan Hansen. "The decline of Central Appalachian coal and the need for economic diversification." Thinking Downstream: White Paper 1 (2010).

Figure 4. Map of Northern Appalachian Counties and Metropolitan Areas



Source: Study Team

The 139 Northern Appalachian counties include a number of metropolitan areas, as identified by the U.S. Census. These include Pittsburgh, Erie, Youngstown, Scranton, Charleston, and Huntington. Cleveland and Akron were excluded from this study, as they are not identified as Appalachian by the federal government. However, these metropolitan areas are adjacent to Appalachia and will likely form part of an archipelago of energy storage clusters that will run from Appalachia to Michigan. The Appalachian counties identified for this Study form around 45% of Pennsylvania's population, 17% of Ohio's, and 100% of West Virginia's.[7]

Energy storage has moved to the front of U.S. strategies to decarbonize. A central problem with the rise of renewable energy is the intermittent nature of such power generation. The sun does not shine all the time and the wind does not blow all the time, so energy drawn from these sources is not as reliable as that provided by the burning of coal or natural gas. Energy drawn from renewable sources needs to be stored and drawn on at different times in order to be effective.

But more than renewable generation drives investment in energy storage for stationary power. Even continuous sources of power, like natural gas, coal and nuclear, are subject to the challenges of an aging, increasingly unreliable grid. Commerce—especially manufacturing— has historically been able to function despite power outages. However, many commercial businesses today (e.g., financial, health and computer services) depend heavily on digital information.

[7] https://www.arc.gov/wp-content/uploads/2021/06/PRB_ARC_Chartbook_ACS_2015-2019_FINAL_2021-06_R1.pdf#page=14

System reliability is critical to viable operations in the contemporary digital economy. Manufacturers who had formerly managed to avoid the adverse effects of interruptible power can no longer endure lost loads. Advanced manufacturing has merged operational and information technologies, leading to a critical need for system reliability. The result of these trends is that businesses need onsite energy storage systems to ensure power remains on during grid-loss events.

The biggest drivers for energy storage, however, relate to applications outside of the power grid. The most important new market for energy storage is for vehicle propulsion, where battery electric storage has become critical to decarbonizing our transportation systems. This report considers Northern Appalachia's energy storage assets in light of the growing national market for energy storage. It then concludes with recommendations for consideration by policymakers interested in fostering the energy storage industry in Northern Appalachia.

2. Defining Energy Storage

Energy storage, as used in this roadmap, is defined as the capability to retain chemical, mechanical, thermal or electrical potential energy for an extended duration that can then be converted into usable electric power when needed.[8] Without storage, electrical energy must be used as soon as it is produced and produced as soon as it is needed, which requires a complex balancing act that utility companies must perform for almost all of the electricity generated in the United States.[9] Every day, utilities across the country predict how much electricity businesses and households will use based on historical patterns, then deliver the amount needed to every single customer, at the precise combination of 120 volts with 60 Hz frequency — the standard for electric alternating current (AC) in the United States. Over delivery can lead to waste and damaged equipment, while under delivery results in service disruptions such as brownouts.[10]

While transmission and distribution lines move energy through space, energy storage technologies move energy through time. Energy generated today — whether from natural gas, solar, wind or any other power source — can be used at another time by storing it. Decoupling the time linkage between the production and consumption of electric power enables greater flexibility in balancing fluctuations in electricity generation and demand that can otherwise lead to

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[8] *See* Baxter, R. (2006). *Energy Storage: A Nontechnical Guide*. PennWell: Tulsa, OK. The 2011 Team NEO study defined energy storage as follows: "the capability of purposely storing various types of energy for use within electricity-based systems, and controllably releasing it for use at another time when a specific demand is to be met." This definition comports with the Baxter definition. Principally, the goal is to exclude oil- and gas-related storage from this analysis. These can, of course, also be converted to electricity, but they have pre-existing, well- established models and technology. We will, however, consider hydrogen and ammonia storage with this analysis, since they are new. Hydrogen, in particular, will be part of the future storage strategy for the grid.

[9] Energy storage currently represents approximately 2% of U.S. generation capacity. *See* "Frequently Asked Questions." (n.d.). *Energy Storage Association.* http://energystorage.org/energy-storage/faq

[10] *See* Energy Storage Association. (n.d.). "Unleashing the Power of Energy Storage." http://energystorage.org/energy-storage

inconsistent, inefficient, and poorer-quality power.[11] Energy storage technologies absorb electrical power during periods of excess generation so that it can be released later in a measured, controlled manner, reconciling the differences between variable electrical sources and consumption. Energy storage enables the control of the electrons flowing through the electrical infrastructure to provide more resilient, superior power quality more efficiently.[12]

2.1 Application-based Framework (Market Segments)

Different technologies and markets constitute what we consider "energy storage." One way to make sense of these diverse technologies and markets is to categorize energy storage by application.[13] Understanding technology in terms of its application is especially helpful for economic development analysis given that the "best" technology (i.e., the most economically efficient one) is dependent on where and how a given technology is deployed to meet a specific storage need.[14] A given technology can be more or less cost-effective based on the needs of a particular application, such as whether more energy density is required, or perhaps longer storage duration is important.

Within this framework, we have identified three general areas of energy storage applications:

- *Grid Storage*. Also known as stationary storage, this refers to storage technologies applied to the network of substations, transformers, and transmission and distribution (T&D) power lines that together make up what is known as the "grid."

- *Transportation Energy Storage*. Storage technologies support a number of transportation modes, including passenger cars, trucks, trains, boats, planes, drones, carts, motorcycles and forklifts. With the advent of smart grids, and as storage is adopted as a grid edge technology, the distinction between the grid and transportation will become blurred. In some cases, electrons may flow not only from grid to vehicle, but also from vehicle to grid during times of electric supply shortage.[15]

- *Consumer Electronics Energy Storage*. Energy storage for portable applications includes the use in smartphones, web-connected wearables, tablets/laptops, medical devices and power tools.

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[11] *Supra, fn* 7 and 8.
[12] *See* Port Authority of Long Beach. (2016). "Energy Storage Technologies White Paper." http://www.polb.com/civica/filebank/blobdload.asp?BlobID=13596
[13] For examples, *see* U.S. Department of Energy. (2017). "Electrical Energy Storage Factual Status Document." https://science.energy.gov/~/media/bes/pdf/reports/2017/EES_BRN_Factual_Doc.pdf
[14] *Supra, fn* 11. Economic efficiency can, and sometimes does, include environmental costs and benefits. Oftentimes, however, environmental costs are controversial and held external to the calculation of the most efficient system.
[15] *See* Energy Storage Association. (n.d.). "Electricity Storage and Plug-in Vehicles." http://energystorage.org/energy-storage/technology-applications/electricity-storage-and-plug-vehicles

This roadmap focuses on the first two applications. As discussed in the market sections below, the largest near-term markets for energy storage in Northern Appalachia will be in the transportation sector. However, grid storage markets may end up offering the most significant opportunity for Northern Appalachia's energy storage industry, especially in light of their implications for smart manufacturing and other areas of the new digital economy.

2.2 Energy Storage Technologies

Another way to understand the range of energy storage options under development and in the market is by referencing the underlying technology powering a given energy storage application. These technologies are generally grouped based on the form of energy they store. Energy storage technologies broadly fall into one of the following five categories:[16]

2.2.1. Mechanical Energy Storage

Mechanical energy storage converts electricity into potential or kinetic energy, which can be converted back to electricity when needed. One example of stored potential energy, seen in Figure 5, involves water storage facilities at two different elevations. Water is held in an upper reservoir (initially pumped there using an electric motor) and then released to a lower reservoir, with a turbine placed between the two facilities to produce electricity when water runs through it.[17] A similar form of storing potential energy uses compressed air. Air is pressurized within a container, then later released to drive a turbine when power is needed.[18] Some parts of Northern Appalachia may have the geographical relief for cost-effective stored hydropower. It may also have some locations, such as abandoned underground salt mines, that could be used for compressed-air technology.

An example of storing energy kinetically can be seen in the rotational kinetic energy of a flywheel, represented in Figure 5.[19] This technology uses a motor-generator power conversion system to convert AC power delivered by the grid or other generating unit into the rotational energy of the rotor. The energy is later released by applying resistance to the spinning rotor, which is typically surrounded by a vacuum to minimize the frictional loss of energy.

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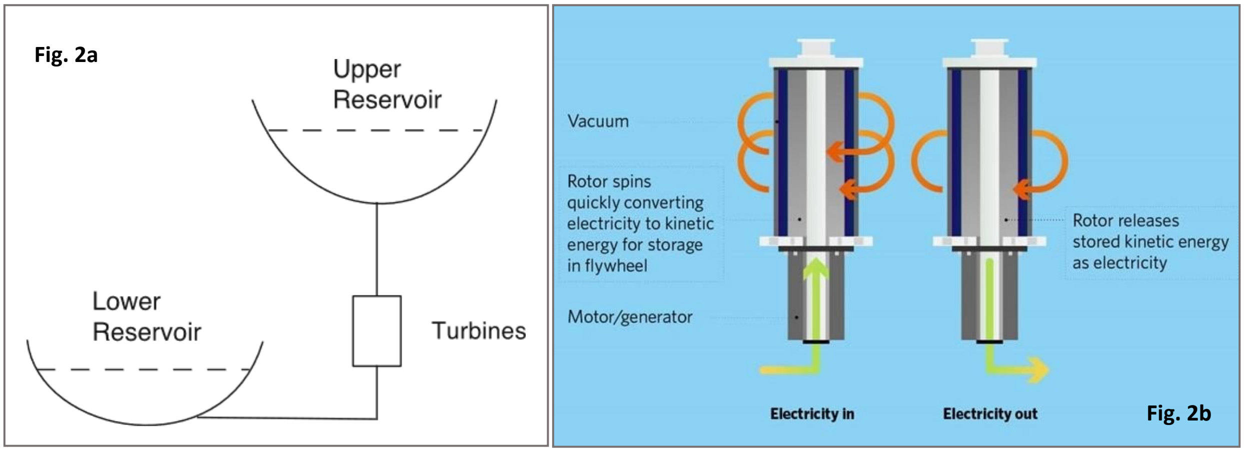
[16] *See* U.S. Department of Energy. (2017). "An Evaluation of Energy Storage Options for Nuclear Power." https://www.osti.gov/servlets/purl/1372488

[17] Huggins, R. (2016). *Energy Storage: Fundamentals, Materials and Applications*, 2nd ed. Springer International Publishing: Switzerland.

[18] *See* Energy Storage Association. (n.d.). "Compressed Air Energy Storage (CAES)." http://energystorage.org/compressed-air-energy-storage-caes

[19] Image Source: *Independent Electricity System Operator (IESO) of Ontario*. http://www.ieso.ca/en/Powering-Tomorrow/Technology/High-Performance-Flywheel-Energy-Storage-Systems-Temporal-Power

Figure 5. Examples of Mechanical Energy Storage

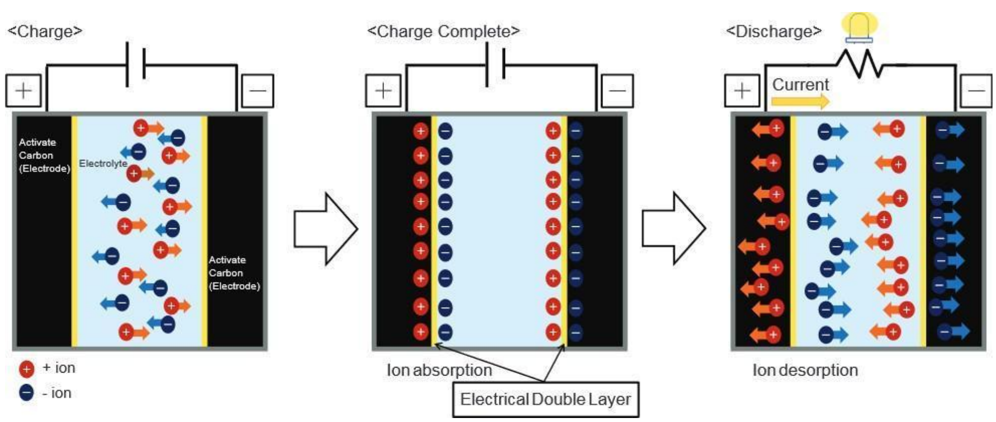


Source: Independent Electricity System Operator of Ontario

2.2.2. Electrical Energy Storage

Electrical energy storage technologies can store energy directly in one of two ways. One way is electromagnetically, where energy is stored in a magnetic field generated by current running through a superconducting wire. The other is electrostatically, where energy is stored in an electric field between two charged electrode plates separated by an electrically insulating material.[20] The latter of these technologies, illustrated in Figure 6, is known as an electrical double-layer capacitor, or supercapacitor. When a current is introduced to the supercapacitor, ions build on either side of the insulator to generate a double layer of charge.[21]

Figure 6. Structure of a Supercapacitor



Source: Mouser Electronics

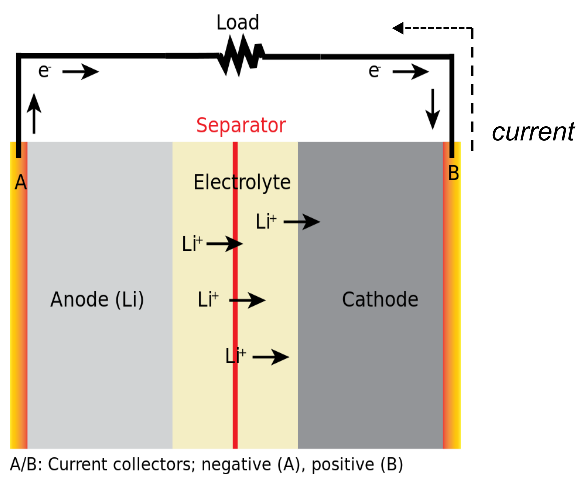
[20] Rasmussen, C. et al. (2013). "Electromagnetic and Electrostatic Storage." *DTU International Energy Report 2013*. http://orbit.dtu.dk/files/60269062/DTU_International_Energy_Report_2013.pdf
[21] Image Source: *Mouser Electronics (Murata Manufacturing).* https://www.mouser.com/pdfDocs/Murata-DMF- DMT_TechnicalGuide.pdf

2.2.3. Electrochemical Energy Storage

The most common form of electrochemical energy storage is the battery, which we can further subdivide into the categories of conventional batteries and flow batteries. The difference between these two types is that conventional batteries store charge in solid electrode systems, while flow batteries rely on storing charge in at least one liquid.

Figure 7 illustrates how the conventional lithium-ion battery works.[22] The electrodes (i.e., the anode and cathode) store the lithium. The electrolyte[23] carries positively charged lithium ions from the anode to the cathode and vice versa through the separator.[24] The movement of the lithium ions creates free electrons in the anode, which creates a charge at the positive current collector. The electrical current then flows from the positive current collector, through the device being powered by the battery, to the negative current collector.[25] While the battery as illustrated in Figure 7 is structurally similar to a supercapacitor, it is important to note that in the case of the battery, energy is indirectly stored in a *chemical* form where a chemical reaction is required to release charges that can perform electrical work.[26]

Figure 7. How a Lithium-ion Battery Functions



Source: *Electrochemical Supercapacitors*

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[22] Image Source: *Stanford University Department of Physics (Wikimedia Commons).* http://large.stanford.edu/courses/2016/ph240/werner1/.

[23] The *electrolyte* is a nonmetallic liquid or solid that conducts ions to carry electrical charges.

[24] The separator, typically a polymer or ceramic, blocks the flow of electrons inside the battery.

[25] See U.S. Department of Energy. (2017). "How Does a Lithium-Ion Battery Work?" https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work

[26] Conway, B. (1999). *Similarities and Differences between Supercapacitors and Batteries for Storing Electrical Energy*. In: Electrochemical Supercapacitors. Springer: Boston, MA. https://link.springer.com/chapter/10.1007%2F978-1-4757-3058-6_2

2.2.4. Hydrogen Energy Storage

Electricity that has been generated by a power plant can be used to produce storable hydrogen through electrolysis, where water molecules are split into their constituent hydrogen and oxygen gases by an electric current. The chemical energy stored in the hydrogen bonds can then be used later in a fuel cell to produce electricity. While electrolysis offers a long-term strategy for developing renewable hydrogen, the common method of making hydrogen today, and for the near term, is through a process of steam reformation of methane. As a result, storage of hydrogen has become of increasing interest for Northern Appalachia, which sits above the large Marcellus and Utica natural gas fields.

Hydrogen is typically stored above ground in steel tanks, but can be stored below ground in geologic formations such as salt domes. This is also of interest to Northern Appalachia, which has many underground salt domes and other potential reservoirs. Once the gas is recovered, it can be burned in a turbine to make electricity, or run through a fuel cell to create a direct current.

2.2.5. Thermal Energy Storage

The most widely used form of thermal energy storage for generating electricity is known as *sensible heat storage*. In a sensible heat thermal energy storage system, a storage medium (e.g., molten salts, sand, rocks or soils) is heated to store energy without undergoing a phase change over the temperature range of the storage process. The heat collected is used to generate steam that, in turn, drives a turbine generator.[27]

Sensible heat storage is widely utilized in concentrated solar power (CSP) applications where the use of thermal energy storage enables a project to produce electricity after the sun has gone down. The medium of choice in CSP plants with thermal energy storage is usually molten salts, which can withstand extremely high temperatures.

Figure 8 illustrates how a CSP plant could generate electrical power using heat collected from sunlight.[28] In this process, a heat transfer fluid is heated as it circulates through the receivers in the collectors. It runs through a heat exchange to generate high-pressure steam, which drives a conventional steam turbine. The spent steam from the turbine is condensed into liquid and re-heated in the steam generator, allowing the process to continue. The storage tank holds the heated medium, such as molten salts, enabling the system to produce electricity after sundown.[29]

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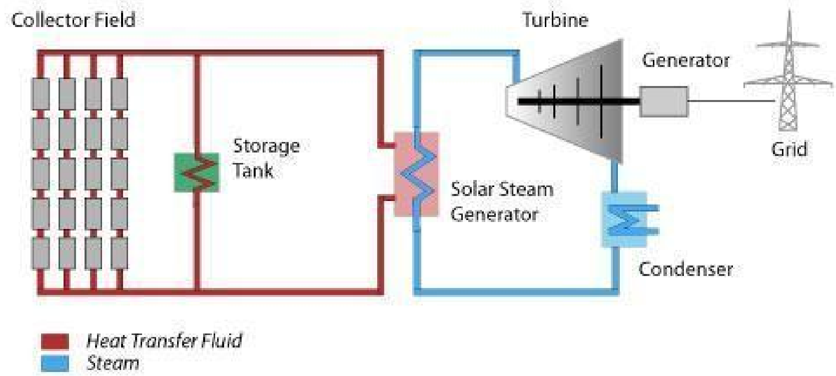
[27] Harvey, A. (2017. "The Latest in Thermal Energy Storage." *POWER Magazine*. https://www.powermag.com/the- latest-in-thermal-energy-storage/?pagenum=3. *See also* Dincer, I., and Rosen, M. (2011). *Thermal Energy Storage: Systems and Applications*, 2[nd] ed. Wiley: Hoboken.

[28] Image Source: "Concentrated Solar Thermal Systems." *Green Rhino Energy*. http://www.greenrhinoenergy.com/solar/technologies/cst_systems.php

[29] *Id.*

Figure 8. Solar Thermal System



Source: Green Rhino Energy

2.3 Energy Storage Systems

The technology medium used to store energy is a part of a greater energy storage *system*. This system generally consists of three parts: the storage medium, a power conversion system (PCS) and balance of plant (BOP), also known as balance of system (BOS).[30] Figure 9 shows an example of an electrochemical-based battery storage system for grid storage.

While the storage medium defines how an energy storage system stores energy (e.g., flywheel energy storage, battery energy storage), the BOS and PCS are crucial enablers of the core technology. These two components of an energy storage system represent from 25% to 40% of overall system costs.[31] Recently, cost reductions for these components have been the main drivers of falling battery prices, and this trend is likely to continue.[32] Continued efforts to standardize the design and engineering for BOS and PCS should accelerate this cost decline, presenting opportunities for increased energy storage growth.[33]

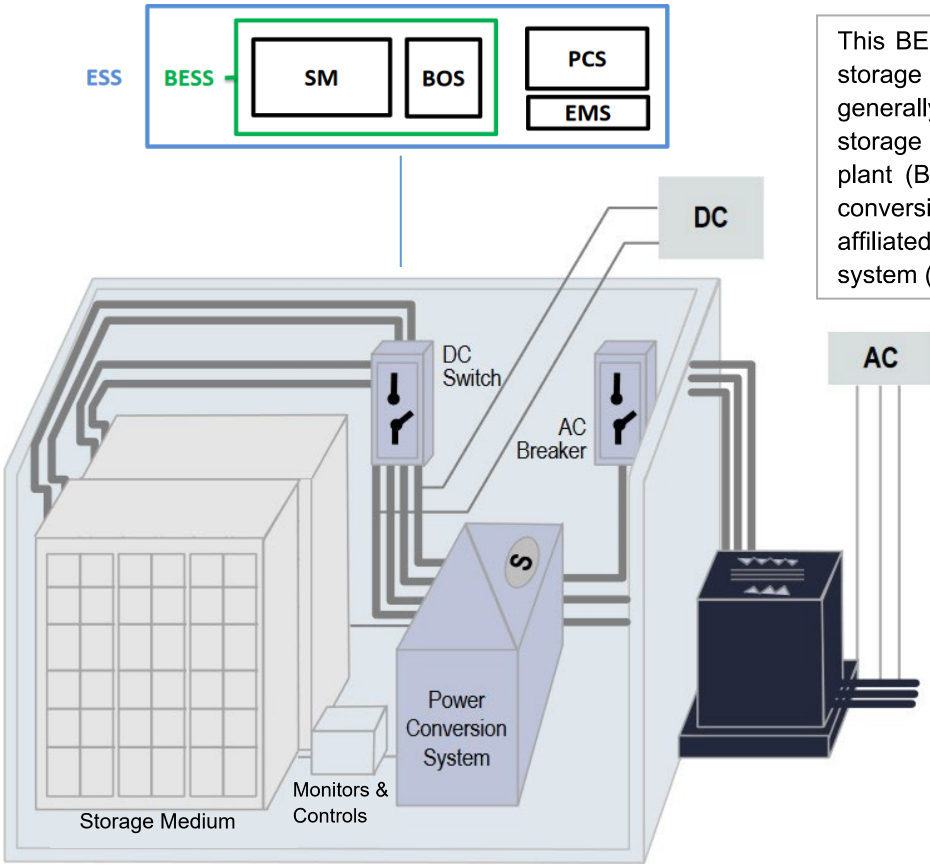
[30] *Supra, fn* 7.

[31] *See the following*: (a) Maloney, P. (2018). "Not so Fast: Battery Prices Will Continue to Decrease, but at a Slower Pace, GTM Says." *Utility Dive*. https://www.utilitydive.com/news/not-so-fast-battery-prices-will-continue-to- decrease-but-at-a-slower-pace/518776/; (b) Kupper, D. et al. (2018). "The Future of Battery Production for Electric Vehicles." *Boston Consulting Group.* https://www.bcg.com/en-us/publications/2018/future-battery-production- electric-vehicles.aspx; and (c) Fu, R. et al. (2018). "2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark." *National Renewable Energy Laboratory*. https://www.nrel.gov/docs/fy19osti/71714.pdf

[32] *Id. See also* Munsell, M. (2016). "Grid-Scale Energy Storage Balance-of-System Costs Will Decline 41% by 2020." *Greentech Media*. https://www.greentechmedia.com/articles/read/grid-scale-energy-storage-balance-of-systems- costs-will-decline-41-by-2020#gs.vUgfJ2kj

[33] *See* Colthorpe, A. (2018). "GTM: Front-Of-Meter Cost Declines Will Slow as Industry Grows 6x Over by 2022." *Energy Storage News*. https://www.energy-storage.news/news/gtm-front-of-meter-cost-declines-will-slow-as- industry-grows-6x-over-by-202

Figure 9. Battery Energy Storage System (BESS)



This BESS, illustrating an energy storage system (ESS) more generally, is composed of a storage medium (SM), balance of plant (BOP or BOS), and power conversion system (PCS) with an affiliated energy management system (EMS).

Source: Sandia National Labs[34]

[34] *See* Sandia National Labs. (2016). "DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA." https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2016/169180.pdf *See also*: (a) Sandia National Labs. (2017). "Energy Storage Project Financing (EESAT 2017)." https://eesat.sandia.gov/wp-content/uploads/2017/12/Richard_Baxter.pdf; and (b) and Sinovoltaics Group. (2017). "Balance of System (BOS): What Is It?" https://sinovoltaics.com/learning-center/basics/balance-of-system-*bos*/

Table 4. Components of a Battery Energy Storage System

System Component	Subcomponents	
Storage Medium	● Battery Cells & Modules	● Racking Frame
Balance of Plant	● Battery Management System (BMS) ● System Control Software ● Monitors and Sensors ● Thermal Management (HVAC Systems)	● Fire Suppression ● Electrical Distribution & Control ● Communication (wired or wireless) ● Container
Power Conversion System	● Inverter ● Rectifier ● Electrical Protection (Switches & Breakers) ● Power Conditioning	● Energy Management System (EMS) - Economic Optimization - Distributed Asset Integration - Data Logging

Source: Sandia National Labs

3. Trends in Energy Storage Markets

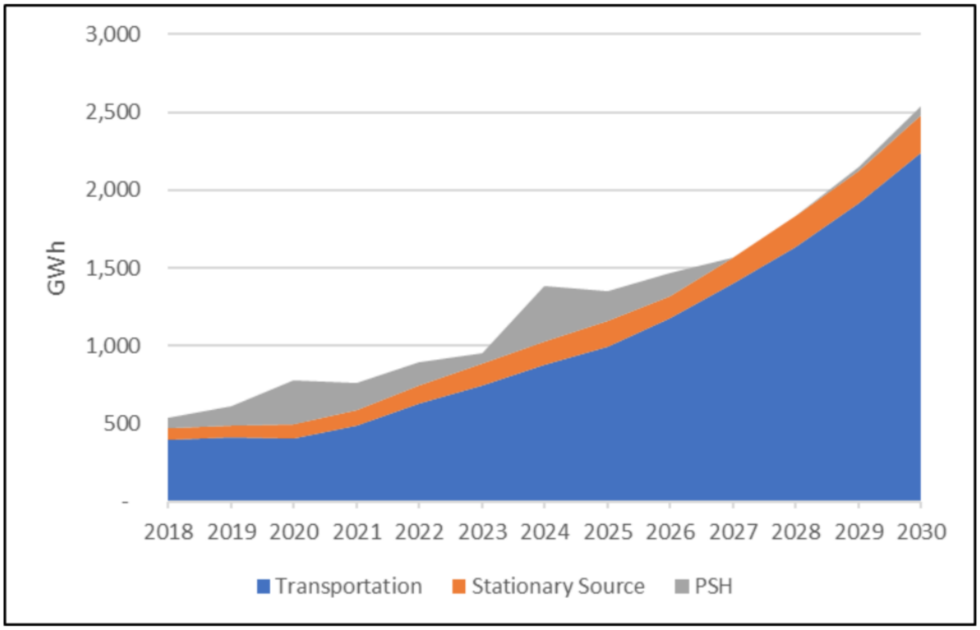
Energy storage is valuable to the power system because of the time flexibility it provides for energy usage. The DOE has identified two major applications for deploying energy storage: electric vehicle transportation and stationary electricity storage, the latter of which includes pumped-storage hydropower (PSH).[35]

Of the two identified general applications, the DOE has projected that transportation will grow precipitously while stationary source storage will grow relatively slowly. The DOE further projects that new PSH deployments will decline over the next decade (*see* Figure 10).[36]

[35] *See* "Energy Storage Grand Challenge: Energy Storage Market Report," Technical Report, U.S. Department of Energy, December 2020. https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf

[36] *Id.*

Figure 10. Anticipated Annual Energy Storage Markets, Near- and Mid-term



Source: DOE (2020)

3.1 Grid Storage Drivers

Utilities and their ratepayers have much to gain in energy system efficiency through deployment of storage. A number of grid costs can be constrained or optimized with energy storage, as described below. Each of these will play a part in the growth of the grid storage market.[37] These deployment strategies can be categorized as:

- *Ancillary services*, including, the provision or absorption of short bursts of power to smooth out supply and demand and to regulate frequency;
- *Peaking capacity*, providing electricity generation to meet system maximum demand;
- *Energy shifting*, deployed when charging and discharge are driven by costs and system flexibility requirements. Storage can be charged during low-cost periods when system demand is low, and discharged during periods of high cost/high demand.
- *Infrastructure investment deferral,* which uses an energy storage system as an alternative to more costly traditional network reinforcement, such as upgrades to transmission and distribution system equipment due to demand growth.

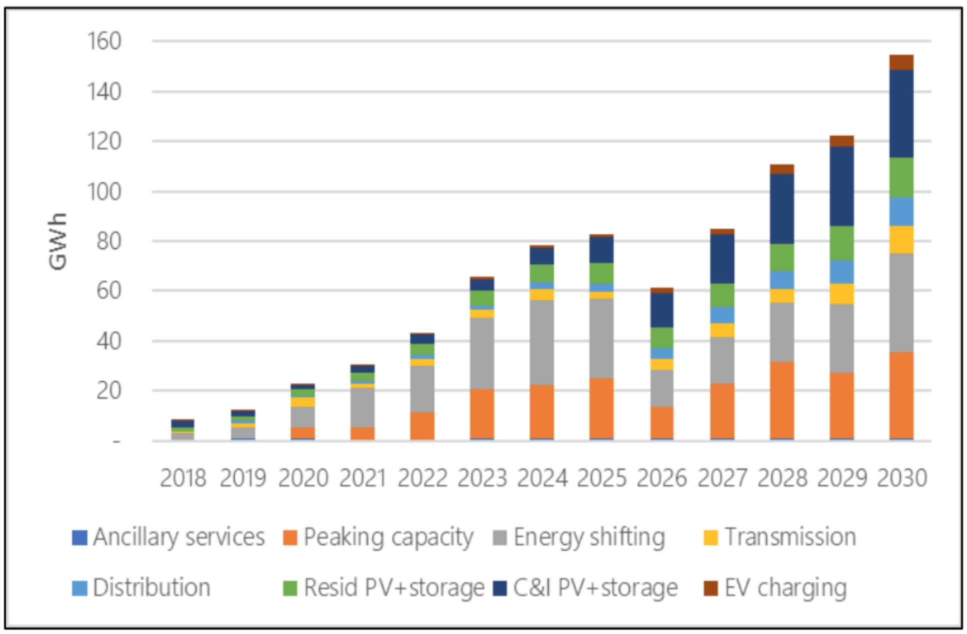
[37] *Id.*, referenced throughout this page.

The Study Team's interview with the innovation director of a Northern Appalachian utility stressed the value of distribution-level storage to improving resiliency of the distribution system in rural areas. Customers can also use distribution-level storage to manage demand charges, which are set by electric distribution companies based upon the customer's peak load contribution to the distribution grid;

- *PV + storage*, energy storage used to increase a customer's rate of self-consumption from a photovoltaic (PV) solar system to cut costs by purchasing less energy from the grid;
- *Electric vehicle charging*, power used for electric vehicles.

Figure 11 illustrates the change in the amount of grid-scale energy capacity available among these energy storage applications worldwide through 2030 as projected by the DOE.[38] The DOE projects PV+ storage, energy shifting, and peaking capacity to be the biggest drivers of grid-related deployments worldwide over the next decade.

Figure 11. Global projected grid-related annual deployments by application (2018–2030)



Source: DOE (2020)

[38] Source: "Energy Storage Grand Challenge: Energy Storage Market Report," Technical Report, U.S. Department of Energy, December 2020. The drop in deployment in 2026 is an artifact of the projection models underlying the DOE's *Market Report* due to a drop in the projections of power plant retirements. Actual deployments are expected to be more evenly spread out.

3.2 Transportation Energy Storage Drivers

The DOE projects the transportation sector will be the main driver of growth in the energy storage industry over the next decade. The following economic factors will likely drive transportation-related energy storage usage and growth over that period.

<u>Consumer demand</u> for more environmentally-friendly vehicles that contribute to lower greenhouse gas emissions will continue to grow over this period. This expansion will occur even if oil prices fall (prices in early 2022 were over $100/bbl as a result of supply shortages caused by COVID and the war in Ukraine). As Avicenne showed in a December 2020 study comparing the total cost of ownership of EV and ICE passenger vehicles by market segment, projected fuel costs for ICE vehicles were about twice that of EVs under similar ownership conditions (e.g., miles driven, years owned, and region of country) even before oil prices rose.[39] While passenger EVs have higher upfront costs than ICE equivalents, their operating costs (including maintenance) are significantly lower, yielding a lower total cost of ownership in the majority of cases, especially for higher mileage scenarios.[40]

- <u>Public policy</u>, in terms of both incentives and prohibitive regulations, will likely be a catalyst for EV market attractiveness and general energy storage growth.[41] In the U.S., in addition to the federal tax credit of up to $7,500 for qualifying EVs, 45 states offer their own incentives ranging from tax credits, utility time-of-use rate reductions, and high-occupancy vehicle (HOV) lane exemptions to promote EV adoption.[42] Nine of those states have formed a coalition committed to having 30% of car sales be zero-emission vehicles by 2030 and 100% by 2050.[43] Of significance to shaping the near- to mid-term future of transportation energy storage are the proposed outright bans on sales of vehicles with internal combustion engines in several countries with large consumer markets—including China, France, Germany and the U.K.—with 2030 being the most common target year among these countries.[44]

- <u>Declining battery prices</u> are bringing EVs closer to price parity with internal combustion engine (ICE) vehicles. Batteries within the lithium-ion family, the dominant form of energy

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[39] *See* Avicenne Energy. (2020). "North American Automotive EV vs ICE Total Cost of Ownership." *Nickel Institute*. https://nickelinstitute.org/media/8d993d0fd3dfd5b/tco-north-american-automotive-final.pdf

[40] *Id.*

[41] Accenture. (2016). "Electric Vehicle Market Attractiveness: Unraveling Challenges and Opportunities." https://www.accenture.com/_acnmedia/PDF-37/accenture-electric-vehicle-market-attractiveness.pdf

[42] *See* National Conference of State Legislatures. (2021). "State Policies Promoting Hybrid and Electric Vehicles." http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx. *See also* "About the ZEV Task Force." *Multi-State ZEV Task Force*. (n.d.). https://www.zevstates.us/

[43] *Id.* Zero-emission vehicles (ZEVs) include pure battery-electric vehicles, plug-in hybrid electric vehicles and hydrogen fuel cell electric vehicles.

[44] *See* Thomson Reuters. (2018). "What's Driving the Electric Vehicle Revolution?" https://blogs.thomsonreuters.com/answerson/whats-driving-the-electric-vehicle-revolution/

storage for passenger vehicles, currently represent around one-third of the cost of an EV.[45] The general consensus in the automotive industry is that for EVs to be competitive with ICE vehicles, costs for these batteries must fall to $100/kWh.[46] This threshold is projected to be reached by the mid-2020s due to increasing economies of scale that have already significantly reduced battery prices to around a fifth of what they were in 2010, as illustrated in Figure 12.[47]

- *Fleet demand* may be a large driver for the transportation energy storage industry over the next decade. Electric trucks by companies such as Rivian could have an impact on fleets that are interested in electrifying for social or economic reasons.[48] According to Allied Market Research, the global electric truck market is projected to grow from $390 million in 2020 to $3.9 billion by 2030, driven by both public policy initiatives and economic factors like reduced noise pollution, lower maintenance cost, and complementarity with self-driving truck technology.[49] Currently, demand for electric trucks is far outpacing supply, leaving a space for manufacturers to fill this space and provide more electric trucks to fleets that want them.[50]

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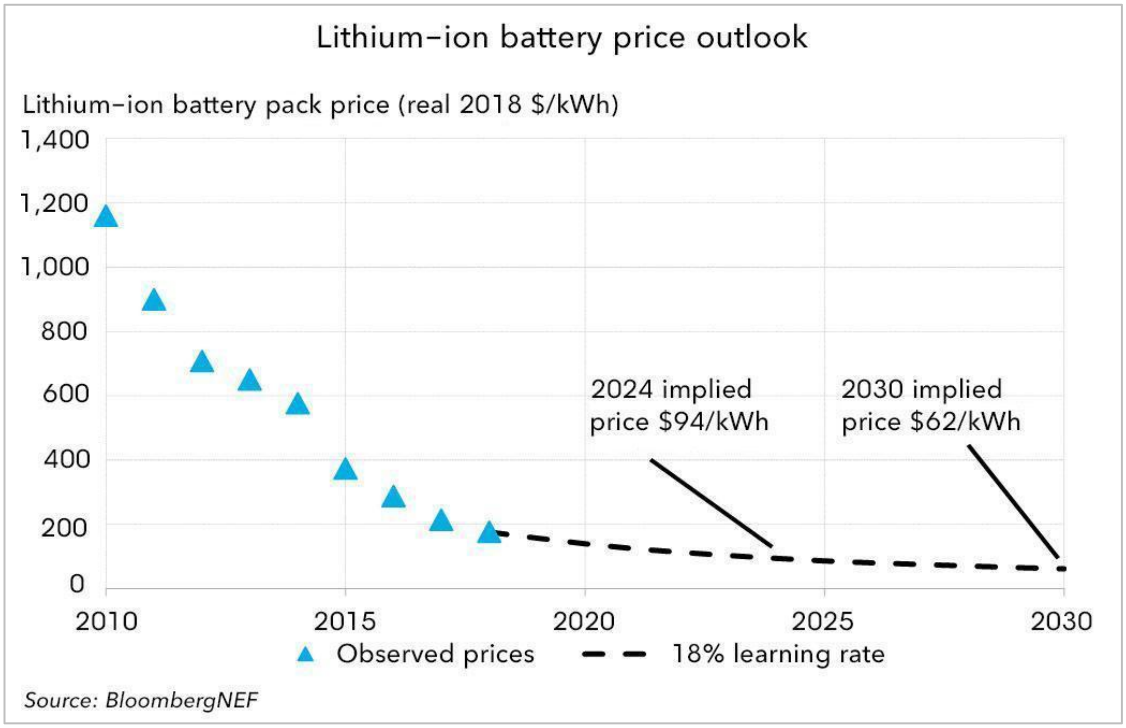
[45] *See* Flowers, S. (2018). "Electric Vehicles: Transportation Disruptor, Part 1." *Wood Mackenzie.* https://www.woodmac.com/news/the-edge/electric-vehicles-transportation-disruptor-part-1/
[46] *Id.*
[47] *See* Goldie-Scot, Logan. (2019). "A Behind the Scenes Take on Lithium-ion Battery Prices." *Bloomberg*. https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[48] Jin, Hyunjoo, "EV truck maker Rivian plans in-house battery cell manufacturing," Reuters, October 1, 2021, Available Online: https://www.reuters.com/business/ev-truck-maker-rivian-plans-in-house-battery-cell-manufacturing-2021-10-02/
[49] Jadhav et al, "Electric Truck Market by Propulsion (Battery Electric Truck, Hybrid Electric Truck, Plug-In Hybrid Electric Truck and Fuel Cell Electric Truck), Vehicle Type (Light Duty Electric Truck, Medium Duty Electric Truck and Heavy-Duty Electric Truck) and Range (Up To 150 Miles, 151 To 300 Miles and Above 300 Miles): Global Opportunity Analysis and Industry Forecast, 2021–2030," Allied Market Research, January 2022, Available Online: https://www.alliedmarketresearch.com/electric-truck-market-A06183.
[50] Fields, Samantha, "As electric pickup trucks come to market — slowly — lots of interest and long waits," Marketplace, February 9, 2022, Available Online: https://www.marketplace.org/2022/02/09/as-electric-pickup-trucks-come-to-market-slowly-lots-of-interest-and-long-waits/

Figure 12. Projected Decline in Battery Prices



- *Vehicle performance* associated with EVs is a value driver for energy storage in transportation that could be as significant as environmental factors. Researchers at the University of California-Davis Institute of Transportation Studies, while investigating the adoption of Teslas among car buyers, found that the most prominent reason for purchasing a Tesla was not environmental concerns but rather the vehicle's performance, particularly its fast acceleration, which offers "visceral rewards" to drivers.[51] An EV's electric motor can maximize torque from a standstill, enabling it to accelerate faster than an ICE vehicle, in which this maximum rotational force or "turning power" is realized more gradually.[52]

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[51] Richards, S. (2017). "How to Combine Three Revolutions in Transportation for Maximum Benefit Worldwide." *UC Davis Institute of Transportation Studies*. https://its.ucdavis.edu/blog-post/page/3/

[52] *See* Fernie, M. (2016). "How Do Electric Vehicles Produce Instant Torque?" *Car Throttle.* https://www.carthrottle.com/post/how-do-electric-vehicles-produce-instant-torque/. *See also* ScienceBlogs. (2009). "What Does Torque in a Car Do?" https://scienceblogs.com/startswithabang/2009/04/21/what-does- torque-in-a-car-do. *Note*: Not all energy storage for EVs is necessarily batteries. Kinetic energy recovery systems (KERS) were originally developed for Formula 1 racing and are being implemented in passenger cars by Volkswagen and Mercedes. Heat from braking that would normally dissipate can be gathered and stored either in a battery or as kinetic energy with a flywheel; the latter form has offered seven seconds per lap of 80 hp boost in racing. For more information on KERS, visit http://large.stanford.edu/courses/2015/ph240/sarkar1

3.3 Market Outlook

Using information presented in the DOE's 2020 *Energy Storage Market Report* and additional information from sources referenced by the report, the Study Team identified market projections for energy storage by application and technology through 2030. Analysts project the market for energy storage for consumer electronics to grow slowly compared to the markets for transportation and stationary applications over the next decade.[53] This market was therefore not included in the Study Team's market projections appearing below.

3.3.1 Grid-related Storage Market

The *Energy Storage Market Report* projects an average annual global market for grid-related energy storage, including pumped storage hydropower, of around 200 GWh between now and 2030. The Study Team converted these projections to dollar amounts using cost-per-GWh estimates found in the DOE's *Grid Energy Storage Technology Cost and Performance Assessment*, also released in 2020 as part of the Energy Storage Grand Challenge.[54]

The Study Team only considered costs pertaining to the energy storage system itself into its estimations of the dollar size of the future global market for grid-related storage. The *Technology Cost and Performance Assessment* includes unit costs for other items such as construction and site work, however these were considered to be local and unlikely to be exported from Northern Appalachia to other parts of the world. They were therefore excluded from the Study Team's market projections.

Since different potential storage technologies have different per-GWh unit costs, the Study Team had to consider how to distribute the DOE's gigawatt-hour market projections for this segment. The Study Team distributed these projected gigawatt hours according to an index developed by the International Renewable Energy Agency (IRENA) for scoring a technology's suitability for grid-related storage applications.[55] The higher a technology scored on this index—based on cost and technical performance—the more projected gigawatt hours the Study Team allocated to it. Figure 13 shows the Study Team's projected annual market for grid-related energy storage based on information gathered from the Energy Storage Grand Challenge reports, and on IRENA's suitability index.[56]

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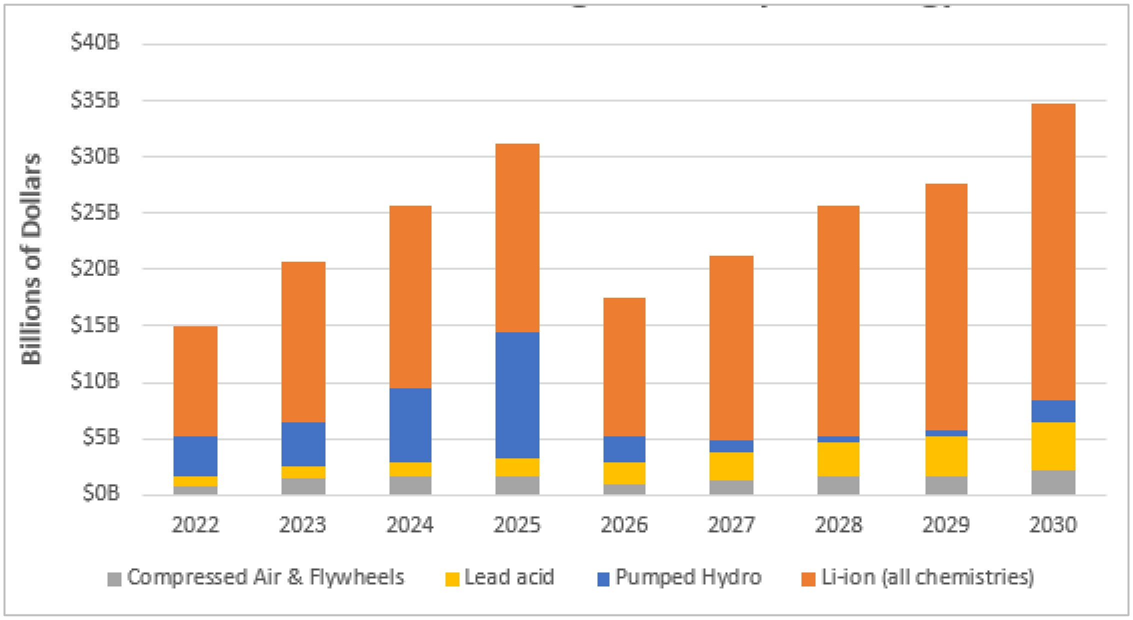
[53] *See* https://www.energy.gov/energy-storage-grand-challenge/downloads/energy-storage-market-report-2020. See also https://rechargebatteries.org/wp-content/uploads/2019/02/Keynote_2_AVICENNE_Christophe-Pillot.pdf

[54] https://www.pnnl.gov/sites/default/files/media/file/Final%20-%20ESGC%20Cost%20Performance%20Report%2012-11-2020.pdf

[55] https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

[56] The drop in deployment in 2026 is an artifact of the projection models underlying the DOE's 2020 *Energy Storage Market Report* due to a drop in the projections of power plant retirements. Actual deployments are expected to be more evenly spread out.

Figure 13. Global Grid-Related Storage Market by Technology



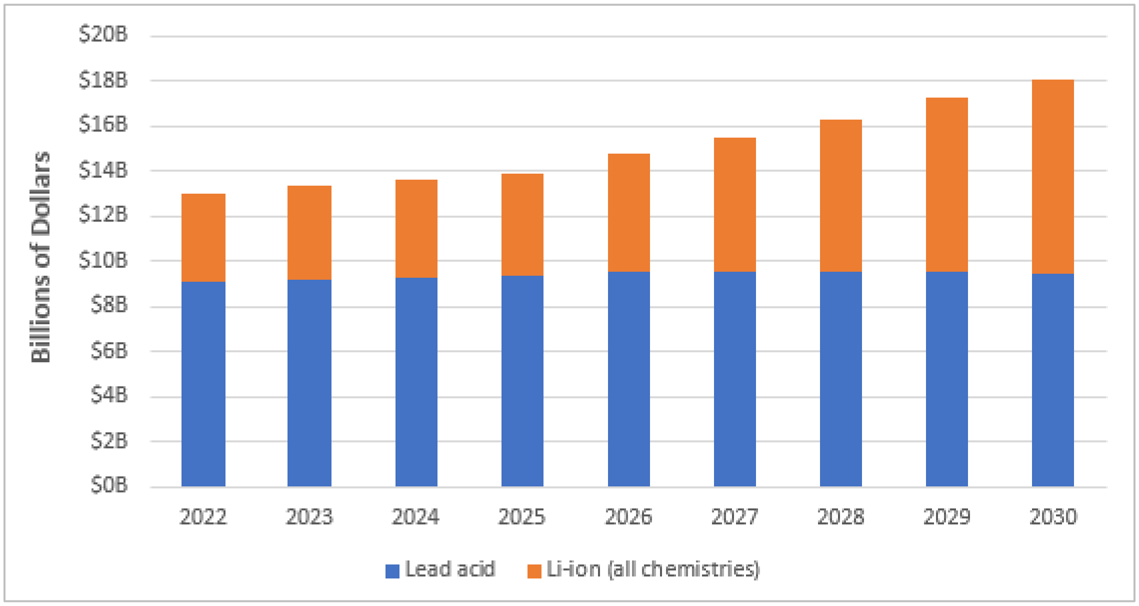
Source: DOE

3.3.2 Industrial Storage Market

The *Energy Storage Market Report* projects an average annual global market for industrial energy storage of around 100 GWh between now and 2030. A little over half of this estimated future stored energy will be for motive applications such as forklifts, while the rest will be for UPS and backup power. Researchers converted these projections to dollar amounts using current and projected cost-per-GWh estimates for industrial storage applications as described by Christophe Pillot of Avicenne, who also projected market share by technology for this segment.[57] Figure 14 shows the projected annual market for industrial energy storage based on information gathered from the Energy Storage Grand Challenge reports and Avicenne.

[57] *See* http://www.avicenne.com/pdf/The%20Rechargeable%20Battery%20Market%20and%20Main%20Trends%202016-2025_C%20Pillot_M%20Sanders_September%202017.pdf. Avicenne's projections form the basis of many of the future cost estimates in the DOE's Energy Storage Grand Challenge reports.

Figure 14. Global Industrial Storage Market by Technology



Source: U.S. Dept of Energy

3.3.3 Transportation Sector

The *Energy Storage Market Report* estimates a global market for transportation energy storage of a little over 600 GWh in 2022, growing to 2,200 GWh by 2030. This market encompasses energy storage for both starting, lighting, and ignition (including for internal combustion vehicles), as well as for propelling electric vehicles. As outlined in the DOE's Energy Storage Grand Challenge reports, the category of mobility storage defined by the DOE also includes hydrogen storage for fuel cell electric vehicles (FCEV).

Mobility storage for propelling electric vehicles is dominated by lithium-ion batteries, which the DOE projects to remain the case through 2030.[58] The Study Team used li-ion battery pack per-kWh unit costs to project the market size (in dollars) for this portion of transportation energy storage. According to Bloomberg New Energy Finance and the Mobility, Logistics & Automotive Research Centre, average battery pack costs will approach $100/kWh by the mid-2020s, falling below $80/kWh by the end of the decade.[59]

Energy storage for vehicle starting, lighting, and ignition (SLI) is largely lead acid-based, which will likely continue through the end of the decade.[60] The Study Team used expected future per-

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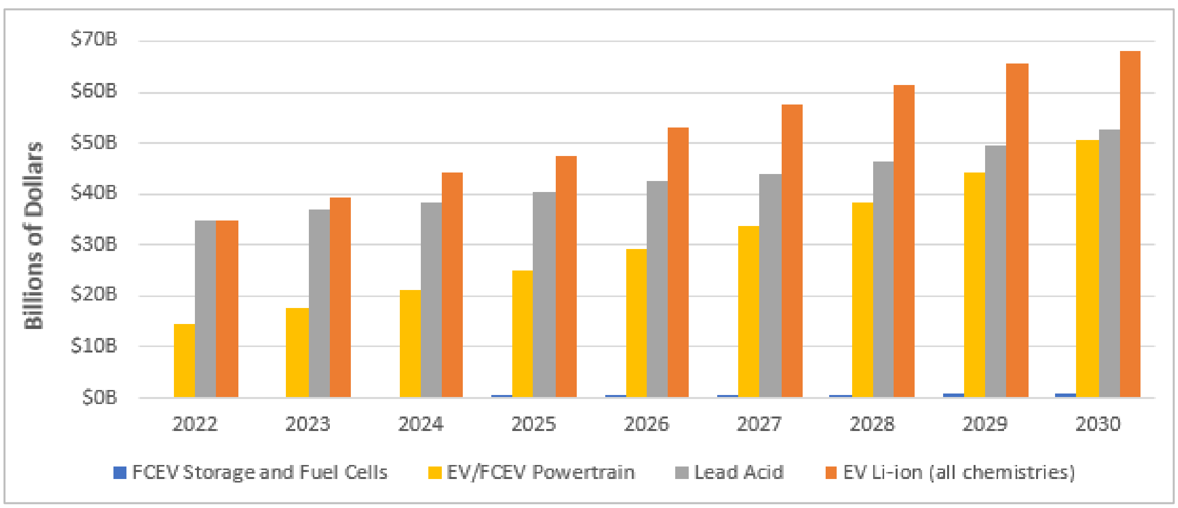
[58] https://www.energy.gov/energy-storage-grand-challenge/downloads/energy-storage-market-report-2020
[59] *See* https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf
[60] *See* https://www.energy.gov/energy-storage-grand-challenge/downloads/energy-storage-market-report-2020. *See also* https://www.emove360.com/wp-content/uploads/2019/10/Impact-of-the-xEV-Market-growth-on-Lithium-Ion-batteries-and-raw-matterials-supply-2018-2030.pdf

kWh unit costs for lead acid batteries, as gathered from presentations by Avicenne,[61] to project the market size (in dollars) for this portion of transportation energy storage.

The hydrogen storage market for FCEVs is expected to be relatively small over the next few years as planning and buildout for refueling infrastructure is in its early stages. However, the Fuel Cell and Hydrogen Energy Association projects FCEV sales to accelerate substantially after 2030, representing more than 15% of the light-duty market and more than 20% of the heavy-duty market by 2040 under likely growth scenarios.[62] The Study Team estimated future hydrogen storage demand for FCEVs (in dollars) using the DOE's storage system cost target of $9/kWh by 2025 and an ultimate long-term cost target of $8/kWh for onboard hydrogen storage.[63]

Figure 15 shows the projected annual global market for transportation energy storage. It includes the market for electric vehicle powertrain components, such as electric drive motors, inverters, and power distributions modules.[64] Altogether, not including EV and FCEV powertrain deployments, the Study Team projects the energy storage market to be a $160 to $170 billion annual market by 2030 across stationary and transportation applications.

Figure 15. Global Transportation Storage Market



Source: U.S. Dept of Energy

[61] https://www.emove360.com/wp-content/uploads/2019/10/Impact-of-the-xEV-Market-growth-on-Lithium-Ion-batteries-and-raw-matterials-supply-2018-2030.pdf
[62] https://www.fchea.org/us-hydrogen-study
[63] *See* https://www.energy.gov/sites/default/files/2017/05/f34/fcto_targets_onboard_hydro_storage_explanation.pdf
[64] For electric vehicle powertrain unit costs, *see* https://neo.ubs.com/shared/d1ZTxnvF2k/. A power-to-energy ratio of 2.5 kW-per-kWh was assumed in calculating the future EV/FCEV powertrain market based on electric drive vehicles currently in the market (*see* https://www.mass.gov/doc/lbe-ev-models-database/download). EVs and FCEVs transmit power to the road using essentially the same drivetrain.

4. Sector Assets in Northern Appalachia and the Region's Competitive Position

Northern Appalachia spans three states and includes areas that have historically played a significant role in the energy industry. Entrepreneurs, policymakers, and researchers can take advantage of both new and legacy assets in the region to grow the region as a hub for energy storage in the United States. This section explains the major categories of assets Northern Appalachia currently has that can grow the energy storage industry in the region.

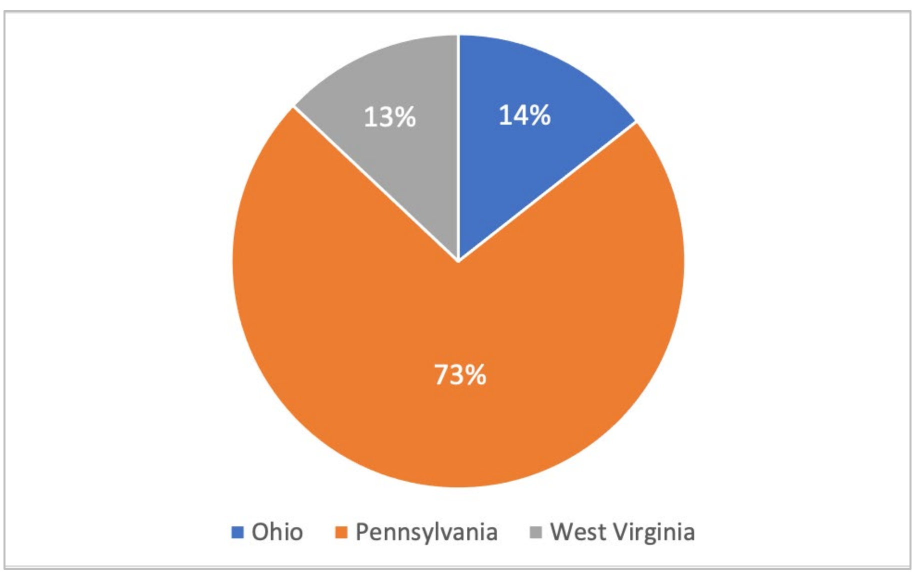
4.1 Commercial Assets

The Study Team compiled a database of companies with the potential to play a role in Northern Appalachia's growing energy storage industry. Each private-sector firm on this asset list was categorized according to its number of employees and the function served by the company within Northern Appalachia (e.g., manufacturing, research & development, etc.)

The Study Team estimated the number of employees for each local business establishment within energy storage using company profiles from third-party databases such as D&B Hoovers, Mergent Intellect, Reference USA, and the Thomas Register of American Manufacturers. The Study Team determined location type using database guidance as well as categorization done by Google Maps profiles of company locations.

Nearly three-quarters of the commercial assets the project team compiled were in Pennsylvania, with the remaining quarter split nearly evenly between West Virginia and Appalachian Ohio.

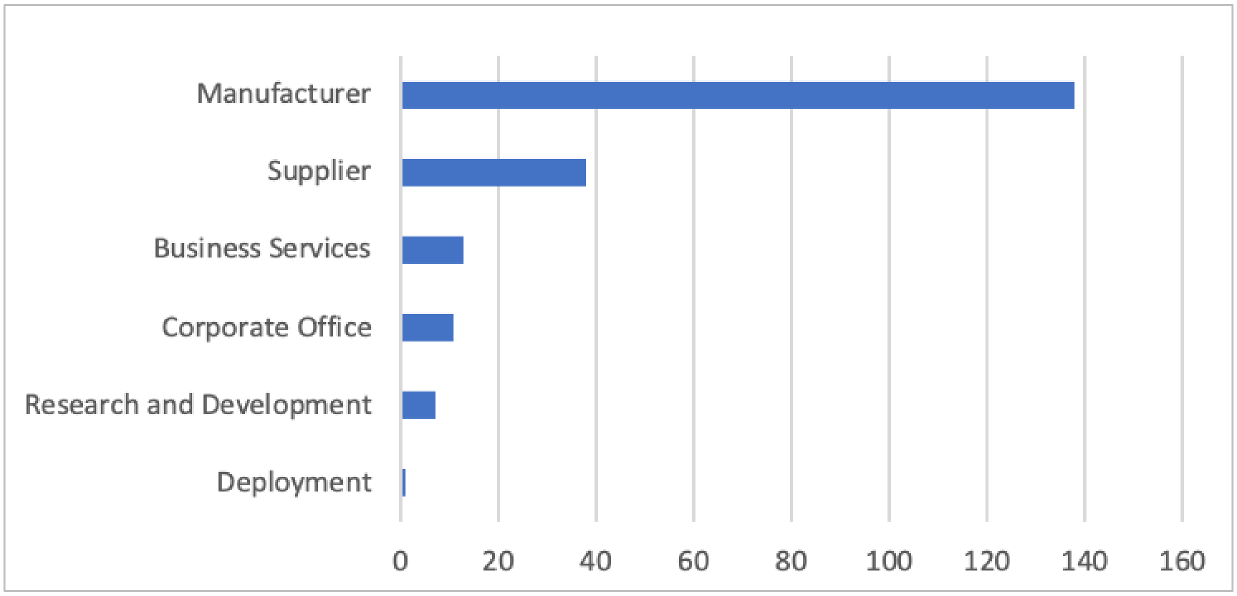
Figure 16. Geographic Distribution of Northern Appalachian Commercial Energy Storage Assets, 2021



Source: Study Team Asset Database

Overall, two-thirds of commercial assets identified by the Study Team were manufacturers. The second most common commercial asset was suppliers, which made up a little under one in five commercial assets in the region, and business services, corporate offices, and research and development, which combined make up about one in seven assets in the region.

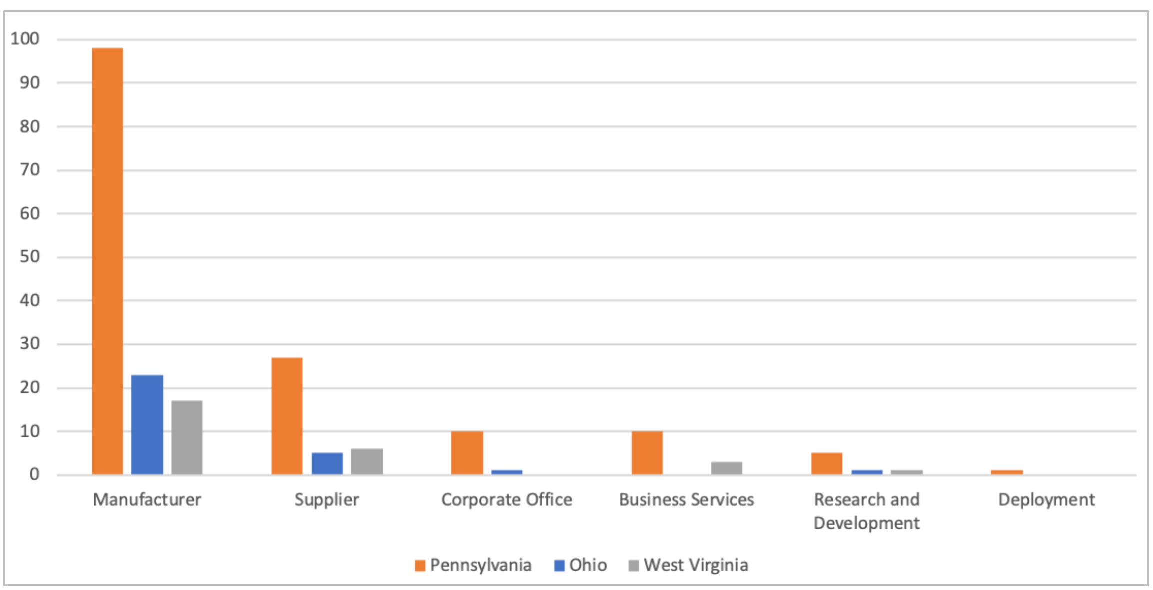
Figure 17. Commercial Energy Storage Assets in Northern Appalachia by Function



Source: Study Team Asset database

Figure 18 shows the number of energy storage assets by function and state. Overall, nearly half the assets the Study Team identified were manufacturers from Pennsylvania.

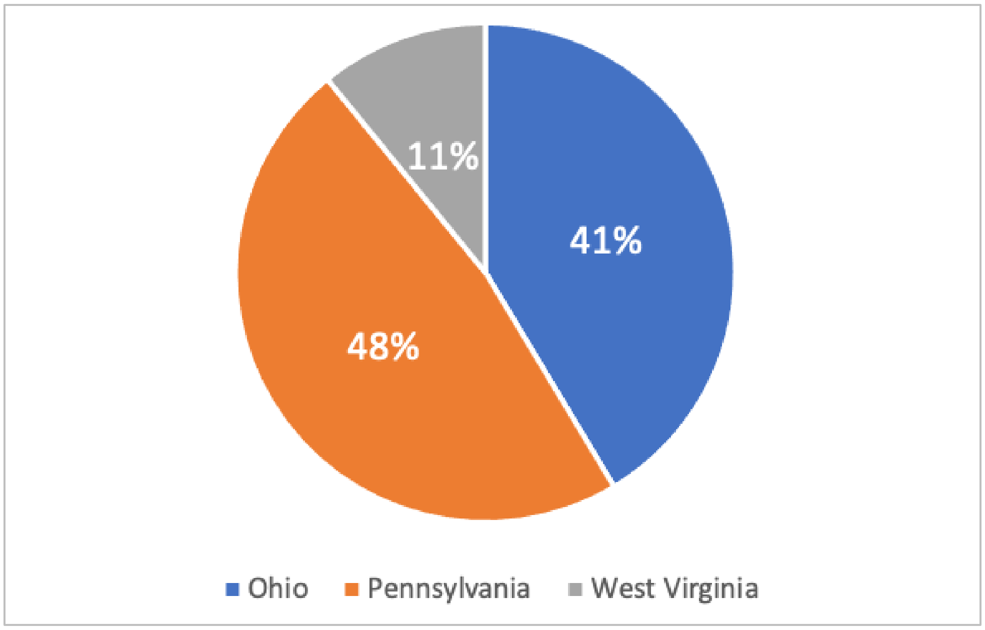
Figure 18. Number of Commercial Energy Storage Assets by Function and State



Source: Study Team Asset Database

The Study Team's compilation of asset data for energy storage yielded an estimated 17,000 workers employed by 209 companies in Northern Appalachia. As of 2021, approximately 7,000 of these employees are in Ohio, while 8,000 and 2,000 are in Pennsylvania and West Virginia, respectively (*see* Figure 19).

Figure 19. Commercial Energy Storage Jobs in Northern Appalachia by State



Source: Study Team Asset Database

4.2 Structural Assets

Northern Appalachian energy storage companies do not exist within a vacuum. They occupy a space within an ecosystem of institutions dedicated to more efficient management of energy generation and usage. This regional energy storage ecosystem is represented below in Figure 20.

Figure 20. Structural Assets in Northern Appalachia

- University of Pittsburgh
- West Virginia University
- Ohio University
- Carnegie Mellon University
- Penn State University
- Marshall University
- Touchstone Research Laboratory
- National Energy Technology Laboratory
- Youngstown State University

- AEP Ohio
- Mon Power
- Appalachian Power Company
- Penn Power
- Duquesne Light Company
- West Penn Power
- Penelec
- Touchstone Energy (electric co-ops)
- American Public Power Association (municipal utilities)

- Appalachian Center for Economic Networks
- Ben Franklin Technology Partners
- BRITE Energy Partners
- Idea Foundry
- Innovation Works
- TekRidge Center
- Ten50
- Tri County Business Dev. Center
- West Virginia Hive Network

- Draper Triangle
- JobsOhio R&D Center Grant
- Mountain State Capital
- Mountaineer Capital L.P.
- Novitas Capital
- Smithfield Trust
- Valley Growth Ventures
- Vantage Ventures

- Ohio Southeast Economic Development
- WV/Ohio/PA Manufacturers Associations
- WV Manufacturing Extension Partnership/MAGNET
- PPG Industries
- Alcoa

4.3 Universities and Research Labs

Universities are often the center of industry clusters, not only providing research and technological support, but also support for companies seeking business, marketing, legal, and workforce expertise.[65] Research labs can fill a similar niche, though they are usually more focused on research and development in particular and often focused specifically on development of a certain type of technology. Northern Appalachia has a number of university and research lab assets that could be valuable to a fledgling energy storage industry.

- *Carnegie Mellon University.* Carnegie Mellon University is home to the Wilton E. Scott Institute for Energy Innovation, a research initiative focused on improving energy efficiency and developing new, clean, affordable and sustainable energy sources.[66] Many chemists, engineers, and materials scientists in this institute focus specifically on energy storage.

  The Institute hosts energy storage events, including a recent panel discussion on batteries and energy storage.[67] Education programs like these can disseminate information about energy storage to the public and provide space for people in the energy storage industry to meet and interact with one another.

  Carnegie Mellon also has researchers studying battery storage in its Mechanical Engineering Department.[68] These researchers are developing technologies for storage devices and to improve storage efficiency.

- *Marshall University.* West Virginia's Marshall University is home to energy storage research, including work by Dr. Tarek Masaud, who is conducting research on the technical and economic aspects of energy storage systems in microgrids and the distribution network.[69] Also doing energy storage research at Marshall is Dr. Asad A. Salem, an engineer who has conducted research on energy storage for renewables among other related topics.[70]

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[65] Gradeck, Robert, Lena Andrews, and Jerry Paytas. "Universities and the Development of Industry Clusters." *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship* (2004).
[66] University, Carnegie Mellon. "About - Wilton E. Scott Institute for Energy Innovation - Carnegie Mellon University." About - Wilton E. Scott Institute for Energy Innovation - Carnegie Mellon University. Accessed October 12, 2021. https://www.cmu.edu/energy/about/index.html.
[67] "Batteries and the Future of Energy Storage," Panel Discussion, Scott Institute for Energy Innovation, Carnegie Mellon University, May 06, 2021, information available online: https://engineering.cmu.edu/news-events/events/2021/05/06-energy-storage.html
[68] "Energy and environment," Mechanical Engineering, Carnegie Mellon University, 2021, available online: https://www.meche.engineering.cmu.edu/research/energy-environment.html
[69] "Faculty Profile - Masaud," College of Engineering and Computer Sciences, Marshall University, 2021, Available Online: https://www.marshall.edu/cecs/p-masaud/
[70] "Faculty Profile - Dr. Asad A. Salem," College of Engineering and Computer Sciences, Marshall University, 2021, Available Online: https://www.marshall.edu/cecs/faculty-profile-dr-asad-a-salem/

- *National Energy Technology Laboratory.* The DOE's National Energy Technology Laboratory has an office in Pittsburgh. The National Energy Technology Laboratory currently has a program in energy storage for fossil fuel energy systems focused on improving the reliability of fossil fuels with energy storage technologies.[71] The laboratory could be an asset for broader development of energy storage technology as well.

- *Ohio University.* Ohio University, located in Athens, Ohio, is a prominent university asset in Appalachian Ohio. Ohio University's Department of Chemical and Biomolecular Engineering has faculty that conduct research on advanced energy storage, providing technological research that can be valuable to companies working in the energy storage industry in Northern Appalachia.[72]

- *Pennsylvania State University.* Pennsylvania State University is a leading resource for battery storage research in Northern Appalachia. It is home to the Battery and Energy Storage Technology (BEST) Center, a center that has been bringing together the university's expertise in energy storage, fostering collaboration, and providing a focal point for research and education activities for the past decade.[73] This center is home to 11 different labs focused on battery storage and brings together the expertise of over a dozen researchers in the university focused on battery storage.

- *University of Pittsburgh.* The University of Pittsburgh is home to the Energy Innovation Center, an outward-facing center focused specifically on engaging corporate and community leaders, aligning workforce development and education, developing and demonstrating technology, and incubating businesses to support emerging clean and sustainable energy markets.[74] While many of these university and research lab resources focus on basic and applied research, this center is focused on business application and is an asset for companies hoping to apply battery storage technology but looking for business support.

  The University of Pittsburgh also has its own solar storage application being developed by Dr. James McKone.[75] Dr. McKone is working with small businesses to advance renewable energy and improve storage using solar-powered technology.

  Also at Pitt, the *Energy GRID Institute* acts as a nexus for collaborative research, development, and demonstration around energy storage, encouraging economic growth

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[71] "Energy Storage for Fossil Fuel Energy Systems," National Energy Technology Library, Available online: https://netl.doe.gov/coal/crosscutting/energy-storage
[72] "Research," Department of Chemical and Biomolecular Engineering, Russ College, Ohio University, 2021, Available Online: https://www.ohio.edu/engineering/chemical/research
[73] "Best Center: Energy & Battery Storage Technology," Pennsylvania State University, 2021, Available Online: https://best.psu.edu/.
[74] "Energy Innovation Center," Swanson Engineering, University of Pittsburgh, Available Online: https://www.engineeringx.pitt.edu/EIC/
[75] Russell, Leah, "Storing the Sun's Energy," Pitt Swanson Engineering Virtual Newsroom, May 20, 2021, Available Online: https://news.engineering.pitt.edu/storing-the-suns-energy/

and job creation by leveraging public/private partnerships to enhance the commercialization of novel utility-scale storage products.[76] The Institute also has its own energy storage technologies lab and energy-related incubator space for start-ups.[77]

- *Touchstone Research Laboratory.* Touchstone Research Laboratory, located in Triadelphia, West Virginia, provides research and testing that can support energy storage systems, such as equipment failure analysis and testing.[78] Companies involved in innovation, research and development could use Touchstone when developing new storage technology.

- *West Virginia University.* West Virginia University is home to the Energy Institute, a center focused on undertaking and promoting energy research and connecting people doing energy research across the university.[79] Energy technology is researched broadly in the Institute[80] and a number of faculty and staff are active in developing and incubating energy storage companies according to interviews conducted by the Study Team.

- *Youngstown State University.* In January of 2021, the DOE announced that it was partnering with Youngstown State University and DOE's Oak Ridge National Laboratory to develop an Energy Storage Workforce Innovation Center, which will serve as a training center based in the Midwest.[81] This investment will position this Northern Appalachian university as a Midwest hub for innovation in the energy storage workforce.

4.4 Innovation Funding

Funding for startup ventures is key for any regional industry relying on new technology. An interview the Study Team held with an entrepreneur in West Virginia revealed at least some entrepreneurs see innovation funding in the region as a strength, with local funders interested in funding local projects in an area for energy storage development that is less saturated than California. Below are descriptions of many of the funding resources available throughout Northern Appalachia for innovation, including new ventures in energy storage.

- *Draper Triangle.* Draper Triangle is a Pittsburgh-based venture capital firm that positions itself as a regional venture capital leader. This firm is focused on technological innovation

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[76] "Energy Grid Institute," 2021, Available Online: http://grid.pitt.edu/
[77] *See* https://www.engineering.pitt.edu/contentassets/f8021ea40ba444dca9de2d40da480901/pitt---eic-update-and-grid-institute--reed---november-2016.pdf
[78] "Touchstone Research Laboratory," 2015, Available Online: https://www.trl.com/
[79] "Mission," Energy Institute, West Virginia University, February 17, 2020, Available Online: https://energy.wvu.edu/about/mission
[80] "Energy Technologies," Energy Institute, West Virginia University, 2021, Available Online: https://energy.wvu.edu/expertise/strategic-partnerships-and-technology
[81] "Department of Energy Partners with Youngstown State University and Oak Ridge National Laboratory to Support Battery Manufacturing Workforce," Energy.gov, January 20, 2021, Available Online: https://www.energy.gov/articles/department-energy-partners-youngstown-state-university-and-oak-ridge-national-laboratory

and encourages new companies to step up with new technologies. It also has a track record of backing companies with exits to well-known industry leaders.[82]

- *JobsOhio R&D Center Grant.* This grant is designed to facilitate new corporate R&D centers in Ohio.[83] Energy storage is explicitly listed on the grant website as an example project for use of the grant. It is designed in particular to create physical places for innovation. The total grant has a funding authorization of $100 million.

- *Mountain State Capital.* Mountain State Capital is a West Virginia venture capital firm that invests when a company has found its product-market fit and is ready to scale.[84] Investors for the company prefer to invest in the "greater Appalachian region," which they consider West Virginia, central & western Pennsylvania, eastern Ohio, eastern Kentucky, western Maryland, western Virginia, western North Carolina and eastern Tennessee.

- *Mountaineer Capital L.P.* Mountaineer Capital is a Charleston, West Virginia-based venture capital firm focused on fostering new and existing businesses in West Virginia and neighboring states.[85] It provides initial investments in the $250,000 to $1 million range and also helps fund expansions and buyouts. They have backed companies in industries ranging from firearms to sports to software.

- *Novitas Capital.* Novitas Capital is a venture firm that focuses on early stage technology companies.[86] Novitas is headquartered in Wayne, Pennsylvania. While it focuses on pharmaceuticals and life sciences, it could be a source for funding for energy storage.

- *Smithfield Trust.* Smithfield Trust announced $5.6 million in venture funding in October of 2021.[87] Smithfield is an investment company, but one that focuses on early- and mid-stage investing.[88] Smithfield is especially attractive for innovators in the energy storage industry because it focuses on energy and clean technology with its investments.

- *Valley Growth Ventures.* VGV is a "micro" venture capital investment fund created to generate strong financial returns by supporting high-growth technology companies across

[82] "Portfolio," Draper Triangle, 2021, Available Online: http://drapertriangle.com/portfolio/
[83] "JobsOhio Research & Development (R&D) Center Grant," JobsOhio, 2021, Available Online: https://www.jobsohio.com/why-ohio/incentives/jobsohio-loan-and-grant-programs/r-and-d-grant/
[84] "Mountain State Capital," Mountain State Capital, 2022, Available Online: https://www.mountainstatecapital.com/
[85] "Mountaineer Capital LP," Mountaineer Capital LP, 2016, Available Online: http://www.mountaineercapital.com/
[86] "Novitas Capital," Venture Capital, CB Insights, Available Online: https://www.cbinsights.com/investor/novitas-capital
[87] "Smithfield Trust has 1 Funding Round totaling $5.6M," crunchbase, Available Online: https://www.crunchbase.com/search/funding_rounds/field/organizations/funding_total/smithfield-trust
[88] "PE/VC Smithfield Trust Company," Massinvestor, 2020, Available Online: https://massinvestordatabase.com/publicfirm.php?name=Smithfield+Trust+Company

the state of Ohio, but with an emphasis on the Mahoning Valley.[89] They provide industry expertise, personnel, facilities, and talent network to companies they fund.[90]

- *Vantage Ventures.* Vantage is a venture capital firm associated with John Chambers of Cisco Systems focused on fostering entrepreneurship in West Virginia.[91] They support entrepreneurs in sectors such as FinTech, food security, and facial recognition.[92]

4.5 Scientific Infrastructure and Startup Assistance

In order for an industry to flourish, it needs resources in the form of scientific infrastructure (i.e., centers that help high-tech companies get products to market) and startup centers that help people turn ideas into companies. Below are examples of resources available to help firms take technology from an idea to a product that succeeds in the marketplace.

- *Appalachian Center for Economic Networks.* Located in Athens, Ohio, the Appalachian Center for Economic Networks focuses on supporting innovation and facilitation collaboration among innovative companies in Appalachian Ohio.[93] The Center runs an incubator in Athens, Ohio and a business center in Nelsonville, Ohio. It supports companies in their need for support with business planning, marketing, finances, and office space.[94]

- *Ben Franklin Technology Partners.* The Ben Franklin Technology Partners is an initiative of the Pennsylvania Department of Community and Economic Development and is funded by the Ben Franklin Technology Development Authority.[95] They provide both early-stage, technology-based firms and established manufacturers with funding, business and technical expertise, and access to expert resources.

- *BRITE Energy Innovators.* Located in Warren, Ohio, BRITE Energy Innovators is a business development service that has helped nearly 500 entrepreneurs start companies over the past decade.[96] They provide mentorship, market research, customer discovery, talent acquisition & scaling, and investor connections to companies launching energy technology solutions.

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[89] "Valley Growth Ventures," 2021, Available Online: http://www.valleygrowthventures.com/
[90] "About VGV," 2021, Available Online: http://www.valleygrowthventures.com/about.html
[91] "Our Story," Vantage Ventures, Available Online: https://vantageventures.io/about/
[92] "Opportunities," Vantage Ventures, Available Online: https://vantageventures.io/opportunities/
[93] "Welcome to the Appalachian Center for Economic Networks," Appalachian Center for Economic Networks, 2021, Available Online: https://acenetworks.org/
[94] "New Clients," Appalachian Center for Economic Networks, 2021, Available Online: https://acenetworks.org/services/new-clients/
[95] "Ben Franklin Technology Partners: Investing in Pennsylvania's Future," Ben Franklin Technology Partners, Pennsylvania Department of Community & Economic Development, 2017, Available Online: https://benfranklin.org/
[96] "Power the Future of Entrepreneurship: How BRITE Energy Innovators assists and empowers startups in the energy technology space," June 23, 2021, https://storymaps.arcgis.com/stories/db10a2081a4a48f49b68422a0a7fb7be

- *Idea Foundry.* Pittsburgh's Idea Foundry walks the line between an innovation funding resource and a startup development resource. The Idea Foundry is an organization that both invests in companies and provides business support for them. Some examples of the types of companies Idea Foundry have supported are life-sciences companies, intelligent systems, and robotics.[97] Idea Foundry has also stressed supporting social and environmentally-conscious enterprises, helping foster companies that have made progress on the fronts of human trafficking, affordable housing, agricultural innovation, and economic empowerment. Idea Foundry's track record, resources, and mission could make it a key partner for companies working in the energy storage industry.

- *Innovation Works.* AlphaLab is a Pittsburgh-based software accelerator within the business management consulting practice Innovation Works that focuses on mentoring, educating, and providing resources for early-stage startups.[98] AlphaLab does this by connecting early-stage companies with their network of investors, mentors, partners, and customers. Specific focuses of business development for AlphaLab are sales, marketing, customer acquisition, operations, and fundraising. Software is a key part of any technological breakthrough and energy storage systems will need good software to function well.

- *MegaJoule Ventures.* MegaJoule Ventures is a newer incubator, accelerator, and technical and innovation center in Warren, Ohio working to demonstrate, pilot and scale forward-thinking energy solutions.[99] MegaJoule Ventures, LLC (MJV) provides financial resources for moving very early advanced energy and clean technology start-ups forward through a process of cultivating value and reducing risk.[100] MegaJoule Ventures focuses on technology companies and bridging the gap between technological innovation and commercial viability.

- *The TekRidge Center.* The TekRidge Center supports the growth of relocating and expanding businesses within Lackawanna County, Pennsylvania.[101] They provide support, flexible office space, and mentorship for businesses in the Greater Scranton Chamber of Commerce's Ignite Business Incubator program.

- *Ten50.* Huntington, West Virginia's Ten50 accelerator is a Global Accelerator Network member that focuses on aerospace, rapid prototyping, and technology development.[102] Ten50 offers up to $30,000 per company and takes a 5% equity stake in the company for partnering. It chooses ten companies per cycle and hosts three cycles per year. The accelerator supports early-stage, high-growth companies with funding, office space,

[97] "Our History," Idea Foundry, 2021, Available Online: https://www.ideafoundry.org/about
[98] "AlphaLab," AlphaLab, 2021, Available Online: https://alphalab.org/
[99] "Mission," MJV Vision and Mission, 2022, Available Online: https://megajouleventures.com/about-us/
[100] "Investment Philosophy," Investments, 2022, Available Online: https://megajouleventures.com/services-2/#advanced
[101] "The TekRidge Center," The Scranton Plan, Greater Scranton Chamber of Commerce, 2022, Available Online: https://www.scrantonplan.com/real-estate/the-tekridge-center/
[102] "Ten50," f6s, 2021, Available Online: https://www.f6s.com/ten50/about

software perks, education, mentorship, and fundraising support. The accelerator also provides access to three advanced manufacturing facilities across the state of West Virginia with computer-controlled manufacturing equipment and 3D-printing capabilities.

- *West Virginia Hive Network.* Beckley, WV's West Virginia Hive Network is an accelerator focused on connecting entrepreneurs with the resources and expertise they need to grow a company in West Virginia.[103] West Virginia Hive provides business advising, training, rentable space, funding, and other resources for companies it supports.

4.6 Manufacturing Expertise and Production Process Improvement

For a Northern Appalachian energy storage manufacturing industry to continue to grow, companies will need manufacturing expertise and support. Below are organizations that could be instrumental in providing manufacturing expertise and production process information to energy storage companies in Northern Appalachia.

- *Alcoa.* Headquartered in Pittsburgh, Alcoa is an aluminum manufacturing company that leads the region in aluminum manufacturing. Aluminum has been identified as a critical mineral of high importance for EVs and battery storage.[104] Alcoa could be instrumental in providing an essential building block to companies that are building a nascent energy storage industry in western Pennsylvania and the rest of Northern Appalachia.

- *MAGNET.* The Manufacturing Advocacy and Growth Network is located in Cleveland, Ohio, but it supports manufacturing business development throughout many of Ohio's Appalachian counties. MAGNET is a non-profit consulting group focused on advancing manufacturing through strategic planning, training, and other activities that strengthen operating practices and manufacturing processes.

- *Ohio Southeast Economic Development.* Ohio Southeast Economic Development is a JobsOhio economic development partner that advocates for economic development in the southeast Ohio region.[105] It helps companies by providing resources and incentives, building engagements and partnerships, facilitating communication and connections, building foreign direct investment, and building talent attraction and retention.

- *PPG Industries.* Headquartered in Pittsburgh, PPG Industries is a Fortune 500 supplier of paints, coatings, and specialty materials. PPG is helping vehicle, battery and component

[103] "Welcome to the Hive," Hive, New River Gorge Regional Development Authority, 2021, Available Online: https://wvhive.com/
[104] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions
[105] "Why OhioSE?" Ohio Southeast Economic Development, 2021, Available Online: https://ohiose.com/why-ohiose/

manufacturers accelerate the development of tomorrow's automotive energy storage solutions.[106]

- *West Virginia, Pennsylvania and Ohio Manufacturers Associations.* The West Virginia, Pennsylvania, and Ohio Manufacturers' Associations represent manufacturers across their respective states.[107] The associations provide members access to experts in the areas of environmental protection, workers' compensation, unemployment compensation, tax, and safety. These groups see energy storage as playing an important part in the grid of the future, and could be important partners in realizing greater adoption of storage.[108]

- *Manufacturing Extension Partnership.* The Manufacturing Extension Partnership (MEP) is part of the U.S. Commerce Department's National Institute of Standard and Technology.[109] MEP's network of local service centers focuses on making U.S. manufacturers more competitive by providing expertise in many areas, including process improvement, quality systems, workforce, health and safety, and energy assessments.[110] West Virginia's local MEP center is housed inside the Mining and Industrial Extension at West Virginia University.[111] Ohio's local MEP center is on Ohio State University's main campus,[112] while Pennsylvania has a standalone MEP center located in Williamsport.[113]

4.7 Assessing Northern Appalachia's Competitive Position

The NAATBatt lithium-ion battery supply chain database provides insight into which states have multiple facilities devoted to battery storage.[114] California leads the pack, with over fifty facilities listed in the database. Michigan also has a number of facilities with nearly forty facilities in the database. Massachusetts also has a number of facilities with almost thirty listed. These suggest that these are locations in the United States where the energy storage industry is most competitive.

California's place as the preeminent state for energy storage is reinforced by a 2020 Guidehouse Insights study, which also highlighted New York and Texas as leading states for energy storage development.[115] According to a 2021 report by the U.S. Energy Information Administration, 35%

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[106] https://news.ppg.com/press-releases/press-release-details/2022/PPG-Cellforce-Group-to-Develop-Sustainable-Battery-Solutions/default.aspx
[107] "Who We Are," West Virginia Manufacturers Association, Available Online: https://www.wvma.com/about/who-we-are.html
[108] *See "*Competing to Win: Energy in Focus," National Association of Manufacturers, Available Online: https://www.nam.org/wp-content/uploads/2019/05/PolicyWhitePaper-Energy.pdf
[109] *See* https://www.nist.gov/mep/mep-national-network
[110] "About the West Virginia MEP," West Virginia MEP, Available Online: https://wvmep.com/about-us/
[111] *Id.*
[112] *See* https://u.osu.edu/manufacturing/
[113] *See* https://pamep.org/
[114] "NAATBatt Lithium-Ion Battery Supply Chain Database," Transportation & Mobility Research, NREL, September 2021.
[115] Nhede, Nicholas, "Top 10 US states leading the utility-scale energy storage market," *Smart Energy International*, Jul 18, 2020.

of large-scale battery storage capacity for the electrical grid is in California, followed by Texas and Illinois, at 15% and 9%, respectively.[116] By comparison, Ohio, Pennsylvania, and West Virginia together have 7% of grid-scale storage capacity. California also has dominated the small-scale (i.e, grid-edge) battery storage market, accounting for 83% of all small-scale battery storage power capacity in the U.S.[117]

Where Northern Appalachia can compete with states such as California for the burgeoning energy storage market is along dimensions of human capital, including cost of living. Within an industrial cluster, human capital can be considered the most important resource available. Having a concentration of workers who understand an industry and can contribute to innovation within that industry is key for industrial innovation to occur.

We assessed Northern Appalachia's competitive position in terms of its capacity to attract skilled labor relevant to energy storage compared to other areas that are considered hubs within the emerging energy storage industry. According to the energy industry media, the following regions have been identified as being where "the energy storage industry is happening now":[118]

- San Francisco, CA, is home to multiple companies focused on grid storage, including Primus Power, a maker of flow batteries, and startups such as Advanced Microgrid Solutions, Stem, and Green Charge networks, which are working on using lithium-ion batteries for grid storage solutions. The region is home to three national laboratories: Lawrence Berkeley, Lawrence Livermore and the SLAC National Accelerator.

- Reno, NV, is the location for Tesla's Gigafactory 1, where 20GWh of Li-ion battery production occurs annually through a partnership with Panasonic.

- Holland, MI, is where LG Chem and Johnson Controls produce more than 3 GWh of transportation energy storage per year for auto manufacturers, including GM and Ford.

- Detroit, MI and the surrounding area are home to primarily transportation energy storage, where the likes of Ford and GM have large battery pack assembly plants. Also, the University of Michigan Battery Lab is nearby.

- Charlotte, NC, where companies such as Celgard, Parker Hannifin, Alevo, SGL, FMC Lithium and the German conglomerate Saft either supply parts and materials for, or are

[116] "Battery Storage in the United States: An Update on Market Trends," U.S. Energy Information Administration, U.S. Department of Energy, August 2021, Available Online: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf
[117] *Id.*
[118] Ferris, D. (2017). "Where the Energy Storage Industry is Happening Now." *E&E News*. https://www.eenews.net/stories/1060052447. New York State was also listed as an area, but we determined that this was more prospective than "now." Clearly, however, portions of that state will emerge as a hub for storage technology. Note also that in the 2011 roadmap, three areas were considered as in competition: Holland, MI; Reading, PA; and Northeast Ohio. Neither Reading nor Northeast Ohio are on the list identified by *E&E News*.

integrators of, lithium-ion batteries, especially for grid storage. Also, ABB has an energy storage research center in this region.

To measure how competitive Northern Appalachia is in possessing the human capital required to drive an energy storage cluster, we compared location quotients (LQs) for a selection of engineering occupations in metropolitan statistical areas (MSAs) throughout Northern Appalachia to LQs for the same occupations in the MSAs corresponding to the energy storage hub regions.[119] For this analysis, we also include the adjacent Akron and Cleveland metropolitan areas.[120] LQs measure the relative concentration of an occupation in a given place, with the United States being the basis of comparison in this instance, and can be used to identify regional specialization in an area. A general rule of thumb is that an LQ of 1.2 indicates specialization.[121] Tables 5 through 9 show the LQs for engineering occupations in Northern Appalachia (highlighted in yellow) compared with LQs for the areas identified by *E&E News* as energy storage hubs as well as metropolitan areas in northeast Ohio.[122]

Table 5. LQs for Electrical Engineers

Area Name	Occupation	LQ
Akron, OH	Electrical Engineers	1.87
Detroit, MI	Electrical Engineers	1.85
Grand Rapids, MI	Electrical Engineers	1.34
Pittsburgh, PA	Electrical Engineers	1.33
State College, PA	Electrical Engineers	1.29
San Francisco, CA	Electrical Engineers	1.17
Charlotte, NC	Electrical Engineers	1.02
Williamsport, PA	Electrical Engineers	0.92
Cleveland, OH	Electrical Engineers	0.87
Erie, PA	Electrical Engineers	0.82
Scranton, PA	Electrical Engineers	0.79
Morgantown, WV	Electrical Engineers	0.77
Youngstown, OH	Electrical Engineers	0.61
Charleston, WV	Electrical Engineers	0.51
Huntington, WV	Electrical Engineers	0.50
Reno, NV	Electrical Engineers	0.35

Source: Bureau of Labor Statistics

[119] Bureau of Labor Statistics data used for this analysis was not available for Holland, MI. Data for Grand Rapids, MI, the nearest MSA, was used instead.

[120] Northeast Ohio is part of an earlier study looking at location quotients. *See*: Henning, Mark and Thomas, Andrew R., "Energy Storage Roadmap for Northeast Ohio 2019: Full Report" (2019). Urban Publications. 0 1 2 3 1624. https://engagedscholarship.csuohio.edu/urban_facpub/1624

[121] Nolan, C. (n.d.). “Occupation Clusters.” *Indiana Business Research Center at Indiana University Kelley School of Business.* http://www.incontext.indiana.edu/2010/jan-feb/article3.asp

[122] Nolan, C. (n.d.). “Occupation Clusters.” *Indiana Business Research Center at Indiana University*

Table 6. LQs for Chemical Engineers

Area Name	Occupation	LQ
Charleston, WV	Chemical Engineers	2.38
Cleveland, OH	Chemical Engineers	1.80
Akron, OH	Chemical Engineers	1.77
Charlotte, NC	Chemical Engineers	1.34
Pittsburgh, PA	Chemical Engineers	1.16
San Francisco, CA	Chemical Engineers	0.90
Detroit, MI	Chemical Engineers	0.65

Source: Bureau of Labor Statistics

Table 7. LQs for Materials Engineers

Area Name	Occupation	LQ
Akron, OH	Materials Engineers	4.43
Erie, PA	Materials Engineers	4.12
Youngstown, OH	Materials Engineers	3.77
Cleveland, OH	Materials Engineers	2.11
Detroit, MI	Materials Engineers	1.64
Grand Rapids, MI	Materials Engineers	1.44
Pittsburgh, PA	Materials Engineers	1.26
San Francisco, CA	Materials Engineers	0.61
Charlotte, NC	Materials Engineers	0.49

Source: Bureau of Labor Statistics

Table 8. LQs for Industrial Engineers

Area Name	Occupation	LQ
Detroit, MI	Industrial Engineers	4.47
Grand Rapids, MI	Industrial Engineers	2.76
Akron, OH	Industrial Engineers	1.30
Cleveland, OH	Industrial Engineers	1.19
Erie, PA	Industrial Engineers	1.04
Pittsburgh, PA	Industrial Engineers	0.95
Williamsport, PA	Industrial Engineers	0.94
Charlotte, NC	Industrial Engineers	0.88
Scranton, PA	Industrial Engineers	0.79
Reno, NV	Industrial Engineers	0.75
Youngstown, OH	Industrial Engineers	0.61
Huntington, WV	Industrial Engineers	0.48
San Francisco, CA	Industrial Engineers	0.54
Charleston, WV	Industrial Engineers	0.19

Source: Bureau of Labor Statistics

Table 9. LQs for Mechanical Engineers

Area Name	Occupation	LQ
Detroit, MI	Mechanical Engineers	7.40
Grand Rapids, MI	Mechanical Engineers	3.39
Akron, OH	Mechanical Engineers	1.72
Erie, PA	Mechanical Engineers	1.68
Pittsburgh, PA	Mechanical Engineers	1.62
Cleveland, OH	Mechanical Engineers	1.35
Williamsport, PA	Mechanical Engineers	1.14
Charlotte, NC	Mechanical Engineers	1.05
Scranton, PA	Mechanical Engineers	0.87
Youngstown, OH	Mechanical Engineers	0.81
San Francisco, CA	Mechanical Engineers	0.68
Reno, NV	Mechanical Engineers	0.63
Morgantown, WV	Mechanical Engineers	0.55
Huntington, WV	Mechanical Engineers	0.52
Charleston, WV	Mechanical Engineers	0.21

Source: Bureau of Labor Statistics

Northern Appalachia has some key metropolitan areas with concentrations of skilled labor that are valuable for building an industry cluster in the region. Pittsburgh and State College, PA both meet the "specialization" threshold for electrical engineers. Charleston, WV meets the specialization threshold for chemical engineers and led all of the comparison metropolitan areas the Study Team assessed in that category. Erie, PA, Youngstown, OH, and Pittsburgh, PA all met the specialization threshold for material engineering. Erie and Pittsburgh also met the threshold for mechanical engineering.

Northern Appalachia's ability to attract additional skilled labor to further strengthen its position in developing a storage cluster depends on several factors, the most important of which is the cost of living. The economic development firm Development Counselors International (DCI) found, in a survey accompanying its *Talent Wars* brief on what people look for in jobs and locations, that cost of living was the most important factor for relocation decisions.[123] DCI reported, "Even locations with the highest salaries (e.g., Seattle) are losing talent because sky-high rents are outpacing paychecks."[124]

To better understand Northern Appalachia's cost of living in comparison with the energy storage hub regions, we gathered Bureau of Economic Analysis data on Regional Price Parity (RPP) data for the corresponding MSAs. Regional price parities give a sense of how much higher or lower effective prices are in an area relative to the nation overall as well as between cities.[125] The Bureau of Economic Analysis determines RPPs using the average prices paid by consumers for a mix of goods and services (including housing) consumed in each region. Since RPPs are constructed as indices, with the national average set at 100, they allow for easy comparison of prices between a given area and the nation overall. Table 10 shows us that Appalachian Ohio and West Virginia have the lowest costs of living compared to all comparison metropolitan areas. Pennsylvania's Appalachian metropolitan areas tend to be comparable to Grand Rapids cost of living with the exception of State College, Pennsylvania, which is comparable to national average cost of living.

[123] Development Counsellors International. (2017). "Talent Wars: What People Look for in Jobs and Locations." https://aboutdci.com/wp-content/uploads/2017/03/TalentWars2017.pdf
[124] Handy, E. (2018). "How Cost of Living Affects Talent Attraction." *Livability Media.* https://livability.com/topics/business/how-cost-of-living-affects-talent-attraction
[125] Sen, E., and Scavette, A. (2017). "Regional Spotlight: Purchasing Power Across the U.S." *Federal Reserve Bank of Philadelphia.* https://www.philadelphiafed.org/-/media/research-and-data/publications/economic- insights/2017/q4/rs_purchasing-power.pdf?la=en

Table 10. Cost of Living by Metro Area

Area Name	Price of Goods, Services and Housing Compared to National Average
Youngstown, OH	14.9% lower
Huntington, WV	14.4% lower
Charleston, WV	14% lower
Morgantown, WV	10.2% lower
Cleveland, OH	10.1% lower
Akron, OH	10% lower
Erie, PA	8.7% lower
Scranton, PA	8.5% lower
Grand Rapids, MI	8% lower
Williamsport, PA	8% lower
Pittsburgh, PA	7.6% lower
Charlotte, NC	5.6% lower
Detroit, MI	4.7% lower
Reno, NV	1.6% lower
State College, PA	Equal
San Francisco, CA	34.5% higher

Source: Bureau of Economic Analysis[126]

4.8 Market Opportunities and Supply Chains for Northern Appalachian Energy Storage

This section details the general market opportunities for Northern Appalachia in the energy storage global market. It also addresses how supply chains in Northern Appalachia can factor into the global energy storage market.

4.8.1 Greatest Energy Storage Market Opportunities

Based on the general market outlook put forth in section 3.3, the Study Team was able to derive more detailed market projections for specific pairings of sector applications and energy storage technologies. In the case of lithium-ion storage, this included estimating future market size by battery chemistry. Table 11 shows the application-technology combinations whose market opportunities were considered by the Study Team, given that these are the likeliest pairings to occur over the next 5-7 years based on analyses by IRENA, Avicenne, and others, as described in section 3.3.

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[126] Based on the Bureau of Economic Analysis' most recent index of Regional Price Parities by Metro Area. See Bureau of Economic Analysis. (2019). "Regional Price Parities by State and Metro Area." https://www.bea.gov/data/prices-inflation/regional-price-parities-state-and-metro-area

Table 11. Likeliest Application-Technology Combinations for Energy Storage, 2022-2030

Application Sector	Technology
Grid-related storage	Pumped Hydro Li-ion (NMC) Li-ion (LFP) Li-ion (NCA) Li-ion (LTO) Lead-acid (VRLA) CAES (compressed air) Flywheels
Industrial storage	Li-ion (LFP) Li-ion (LMO) Li-ion (LTO) Li-ion (NCA) Li-ion (NMC) Lead-acid
Transportation storage	EV Battery Pack, Li-ion (LFP) EV Battery Pack, Li-ion (NMC) EV Battery Pack, Li-ion (NCA)
	Li-ion for SLI Lead-acid (SLI) FCEV Storage & Fuel Cell System EV/FCEV Powertrain

Source: Study Team

For purposes of identifying the most promising energy storage market opportunities for Northern Appalachia, this listing of application-technology combinations was further filtered based on the projected size of global demand and the expected market growth rates for these pairings. The most promising application-technology pairings were assumed to be those with the greatest projected share of the entire global market, the highest expected market growth rates, and the most stable expected market growth rates.[127] Table 12 shows the application-technology pairings with the greatest market opportunity based on their projected share of the energy storage market as well as expected growth in demand for them.

[127] The most promising application-technology pairings were determined according to an assigned score. Each of the twenty-one such combinations were ranked according to average annual projected market share, average expected annual growth rates, and variability in expected annual growth rates (based on the standard deviation for these rates) from 2022 through 2030, with less variability signifying a more stable market. The three ranking scales were assumed to have importance-weights of 3, 2, and 1, with market share considered the most important scoring factor and market stability the least. The weighted rankings across the three factors were summed to arrive at a composite score for each application-technology pairing. The Jenks natural breaks method was used to classify these scores into groups of low, medium, and high scores, with the low-score group indicating the highest rank.

Table 12. Greatest Energy Storage Market Opportunities, 2022-2030

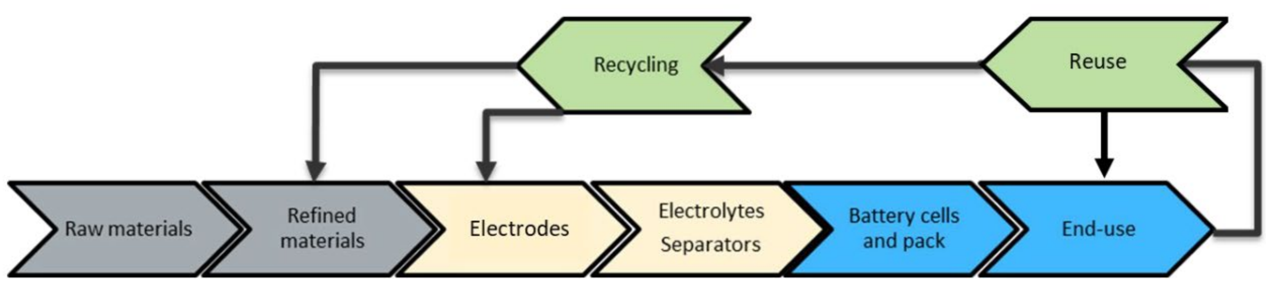
Application Sector	Technology	Average Annual Market (billions)	Average Annual Growth Rate
Grid-related storage	Li-ion (NMC)	$5.2	18.5%
	Li-ion (LFP)	$4.7	18.2%
	Li-ion (NCA)	$5.2	18.5%
	Lead-acid	$1.9	23.4%
Industrial storage	Lead-acid	$9.5	0.5%
Transportation storage	EV Battery Pack, Li-ion (LFP)	$11.3	5.1%
	EV Battery Pack, Li-ion (NMC)	$35.9	10.1%
	Lead-acid, for SLI	$42.4	5.5%
	EV/FCEV Powertrain	$29.1	16.3%

Source: Study Team

4.8.2 Supply Chains for Greatest Market Opportunities

Using a deep-dive energy storage supply chain assessment recently released by the DOE,[128] the Study Team matched the likely to be favorable markets identified above to supply chain segments within those markets. Figure 21 shows a representative battery system supply chain segmented into upstream components (raw and refined materials), midstream components (subcomponents such as electrodes and separators), downstream components (battery cells, packs, and end-use), as well as recycling and recovery.[129] The DOE's assessment included a projection of whether or not there will be significant future demand for each of the individual products and components along this supply chain. Northern Appalachian energy storage assets were mapped to these high-demand component items to identify especially promising market opportunities for the region.

Figure 21. Battery Supply Chain



Source: DOE

[128] https://www.energy.gov/sites/default/files/2022-02/Energy%20Storage%20Supply%20Chain%20Report%20-%20final.pdf
[129] https://www.energy.gov/sites/default/files/2022-02/Energy%20Storage%20Supply%20Chain%20Report%20-%20final.pdf

- *Raw Materials.* Northern Appalachia has no significant mineral deposits for cathode raw materials such as lithium, cobalt, nickel, and manganese.[130] Similarly, the region has few resources for making graphite,[131] which accounts for around 90% of anode materials for lithium ion batteries.[132] While the DOE is currently funding research on transforming coal into battery-grade graphite,[133] the bituminous coal found abundantly in Northern Appalachia has not been found to graphitize, in contrast to other coal types such as lignite.[134]

  One area where Northern Appalachia could see growth in the raw materials segment is in the production of silicon-based anodes, which have 10 times the energy density of their graphite counterparts.[135] Silicon anode startup companies received $1.9 billion in funding over the past decade, with more than one-third of this coming in 2021 alone.[136] By 2030, silicon is forecast to represent 5% of the market for lithium-ion anode materials, up from its current share of about 1%.[137] One of the world's largest producers of silicon metals and silicon-based alloys, Ferroglobe, has two production facilities in Northern Appalachia.[138] While it has historically supplied silicon-based products to the chemical and metal production industries, the company has more recently been actively discussing the development and supply of silicon anode materials with partners in the energy storage sector.[139]

- *Refined Materials.* Corresponding with cathode raw materials, Northern Appalachia does not have significant production capacity for refined, battery-grade cathode materials. The United States in general has very little production capacity for these refined products; for example, it has only 3% of global lithium refining capacity, and no capacity at all for refining nickel, cobalt, and manganese to purity levels required for Li-ion batteries.[140]

  However, similar to the raw materials segment, Northern Appalachia does have expertise in refining some of the materials used for cathodes, albeit to satisfy demand by industries

[130] USGS Mineral Commodity Summaries and Minerals Yearbook for the years 2017 through 2022. https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries https://www.usgs.gov/centers/national-minerals-information-center/minerals-yearbook-metals-and-minerals
[131] https://netl.doe.gov/sites/default/files/netl-file/20VPRACP_Sherwood.pdf.
[132] https://www.benchmarkminerals.com/graphite-anodes-2019-key-talking-points/
[133] https://netl.doe.gov/sites/default/files/2021-05/Carbon-Ore-to-Products-Portfolio-2021.pdf
[134] https://netl.doe.gov/sites/default/files/netl-file/21ACP_Wagner.pdf
[135] https://ucsdnews.ucsd.edu/pressrelease/meng_science_2021
[136] https://www.mining.com/silicon-anode-startups-snagged-1-9bn-in-funding-over-the-past-decade/
[137] *See* https://www.benchmarkminerals.com/graphite-anodes-2019-key-talking-points. *See also* https://www.benchmarkminerals.com/wp-content/uploads/Graphite-COVID-19-Special-Report.pdf
[138] Ferroglobe has production facilities in Beverly, OH and Alloy, WV.
[139] *See* https://www.proactiveinvestors.com/companies/news/955375/neo-battery-materials-inks-agreement-with-ferroglobe-for-silicon-anode-technology-955375.html. *See also* https://investor.ferroglobe.com/news-releases/news-release-details/ferroglobe-signs-joint-development-agreement-biosolar-leading
[140] https://www.energy.gov/sites/default/files/2022-02/Energy%20Storage%20Supply%20Chain%20Report%20-%20final.pdf

outside of energy storage. In particular, Eramet in Marietta, OH, and Felman Production in Letart, WV, each have the refining and processing capacity to produce more than 100,000 metrics tons of manganese alloys annually,[141] primarily for the steel industry, which currently consumes around 90% of all manganese globally.[142] While steel is poised to remain the primary consumer of manganese, the higher profit margins of battery-grade manganese products compared to traditional steel applications may persuade processors to shift some productive capacity toward satisfying demand in the Li-ion battery market.[143]

More mature development of the refined materials segment within the region can be found in the production of refined graphite for anodes. Amsted Graphite Materials, in Anmoore, WV, and SGL Carbon, in St. Marys, PA, both have facilities dedicated to the development and production of battery-grade graphite for Li-ion applications.[144]

- *Subcomponents: Electrodes, Electrolytes, and Separators.* Northern Appalachia, like most of the United States, does not currently possess manufacturing capacity for Li-ion electrodes.[145] Similarly, U.S.-based development and production of electrolytes and separators takes place in other parts of the country.[146] However, the region does possess expertise in developing coatings and binders for electrodes that improve the operational characteristics of batteries (e.g., higher energy density and longer service life), with companies such as PPG and Chemours having a significant presence.[147]

- *Battery Cells, Packs, and End-use.* While not yet operational, the Ultium Cells manufacturing plant in Lordstown, OH—a joint venture between General Motors and LG Energy Solutions slated to come online by mid-2022—will soon be one of two Li-ion battery cell production facilities in the study region (see Figure 22). U.S. battery manufacturer Sparkz plans to start construction of a Gigafactory in West Virginia in 2022 that will produce cobalt-free lithium batteries.[148] Growing demand for electric vehicles will likely present opportunities for the development of additional such facilities in the region.[149]

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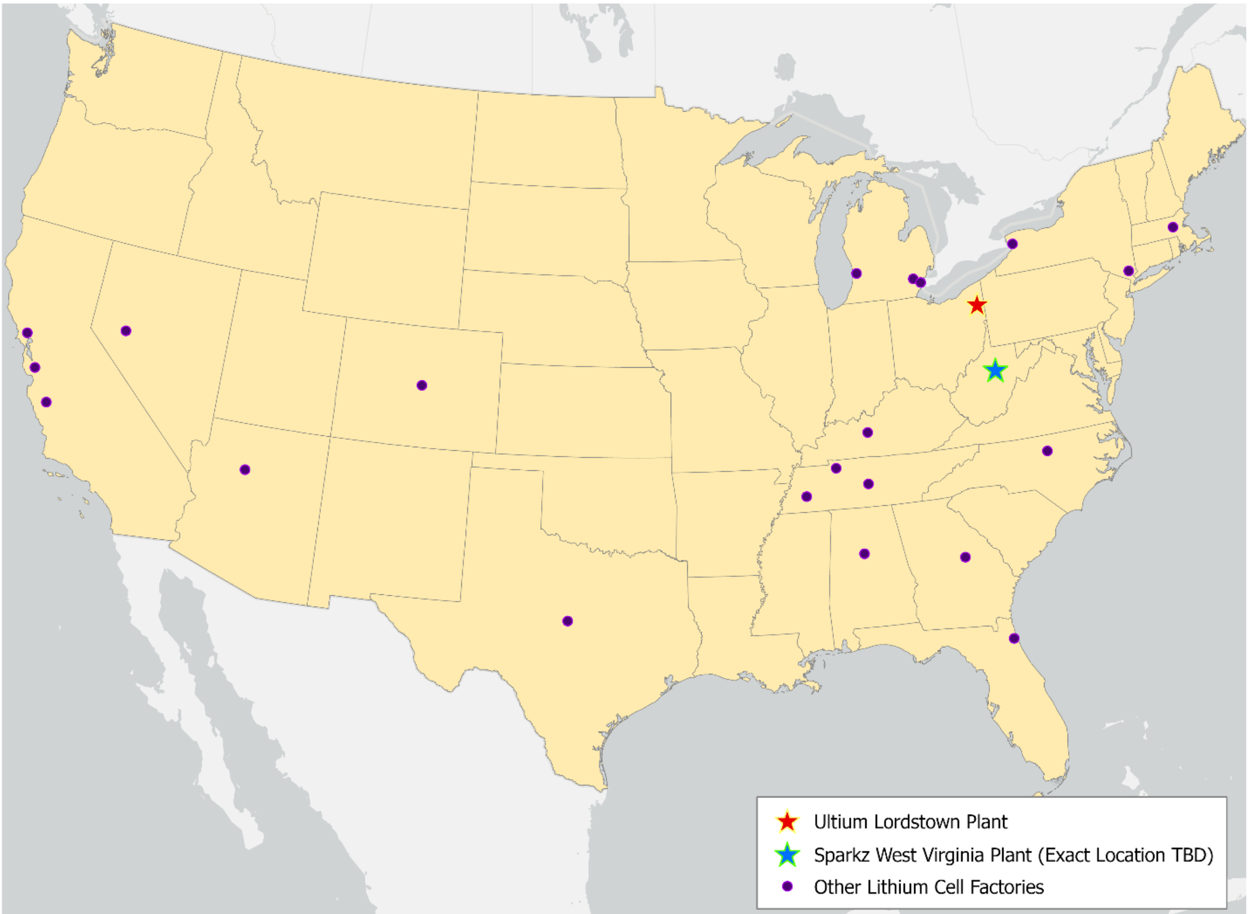
[141] *See* https://www.fpiwv.com/about. *See also* https://www.eramet.com/en/group/subsidiaries/eramet-marietta.
[142] https://pubs.usgs.gov/fs/2014/3087/pdf/fs2014-3087.pdf
[143] *See* https://www.coreconsultantsgroup.com/manganese-no-longer-just-for-steel/
[144] *See* https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html
[145] *See* https://www.ida.org/-/media/feature/publications/l/li/lithium-ion-battery-industrial-base-in-the-us-and-abroad/d-11032.ashx. *See also* https://www.renewableenergyworld.com/storage/in-win-for-ev-supply-chain-u-s-s-first-anode-plant-opens-in-tennessee/
[146] *Id.*
[147] *See following:* http://www.ppgautocoatings.com/Products/Battery-Coatings.aspx; https://corporate.ppg.com/Our-Company/Worldwide-Operations/North-America/Allison-Park; https://www.chemours.com/en/about-chemours/global-reach/washington-works; https://www.chemours.com/es/-/media/files/teflon/intro-to-fluoropolymers.pdf
[148] https://www.electrive.com/2022/03/22/sparkz-to-build-batteries-in-west-virginia/
[149] *See* https://cicenergigune.com/en/blog/north-america-battle-electric-car-battery-gigafactories

Figure 22. Planned and Operational Lithium-based Battery Cell Manufacturing Plants as of 2022



Source: CIC energiGUNE[150]

Growth in demand for electric vehicles in the automotive sector will also present opportunities for companies specializing in electric powertrains that apply stored electrical energy to the road. As described previously in Table 12, this sizeable market is projected to see greater than 16% annual growth between now and 2030. Northern Appalachia is well-represented in this part of the end-use segment. Companies such as Höganäs and Carpenter Technology—industry leaders in the production of materials that improve the performance and efficiency of electric motors for drivetrain applications—have multiple locations within the region.[151] Additionally, Toyota has invested hundreds of millions of dollars in the region to produce hybrid transaxles as part of its continued transition to

[150] *Id. See also* https://cicenergigune.com/en/blog/north-america-accelerates-commitment-development-gigafactory-industry

[151] *See* https://www.hoganas.com/en/Industries/automotive-transportation. *See also* https://www.carpentertechnology.com/transportation/electric-vehicles.

vehicle electrification,[152] further suggesting a burgeoning cluster within Northern Appalachia for electric vehicle drive systems.

Compared to the transportation sectors, energy storage for stationary end-use applications seems less well-represented in the region. A review of utility-scale system integrators revealed only one—Mitsubishi Electric Power Products in Warrendale, PA—with R&D and/or production capacity inside the study area.[153]

However, the region does include Amphenol, whose facility in St. Mary's, PA produces advanced sensors for thermal runaway detection in lithium-based energy storage systems.[154]

- *End of Life: Recycle and Reuse.* The ability to recycle and recover key battery materials will become increasingly important given the near- to mid-term supply constraints for mineral commodities such as lithium, cobalt, nickel, and manganese due to scarcity and political uncertainty. While the development of refineries for these materials tops most U.S. battery wish lists, it is not clear how soon such processing capacity will come online.[155] Recycling capacity will therefore be critical to meeting the demand for critical minerals.

  Northern Appalachia already possesses some of this recycling capacity, with more coming in the near future. INMETCO's industrial waste and battery recycling operations just north of Pittsburgh have recovered at least 3,350 tons of nickel annually in previous years,[156] with this recycling capacity likely higher more recently after a 2016 expansion.[157] The region's recycling capacity will expand further by early 2023, when the lithium-ion battery recycler Li-Cycle is projected to open a plant on the same site as Ultium Cells' manufacturing facility in Lordstown.[158] Once complete, Li-Cycle's facility will have the capacity to process up to 15,000 tons of battery scrap and battery material annually.[159] Additionally, startup companies such as West Virginia's Parthian Battery Solutions are pursuing second-life reuse of EV batteries for stationary applications, which can be more

[152] *See* https://www.greencarcongress.com/2021/11/20211112-tmmwv-1.html. *See also* https://www.wtrf.com/west-virginia/toyota-expanding-electric-car-parts-production-at-west-virginia-plant/
[153] For listings of stationary energy storage system integrators, see the following: https://guidehouseinsights.com/reports/guidehouse-insights-leaderboard-utility-scale-energy-storage-systems-integrators; https://www.ysgsolar.com/blog/top-50-energy-storage-companies-2021-ysg-solar. Mitsubishi's Warrendale location is the site of its corporate headquarters and is where engineering staff with battery energy storage system (BESS) design expertise are employed.
[154] https://www.nrel.gov/transportation/li-ion-battery-supply-chain-database.html
[155] https://www.reuters.com/business/energy/nickel-refinery-tops-us-battery-metals-wish-list-andy-home-2021-06-14/
[156] http://www.irrc.state.pa.us/docs/2451/COMMENTS_PUBLIC/2451%2012-21-04%20BATCH%201.pdf
[157] *See* https://www.recyclingtoday.com/article/alcoa-smelting-refining-capacity-cuts/
[158] https://li-cycle.com/news/licycle-lordstown-battery-recycling-facility-is-companys-6th-and-largest/
[159] *Id.*

cost-effective than metallurgic recycling while at the same time helping to relieve supply stresses in the Li-ion market.[160]

Table 13 summarizes Northern Appalachian assets within supply chains for energy storage markets that are most likely to see strong demand through 2030.

Table 13. Northern Appalachian Supply Chain Assets for High-Demand Energy Storage Markets

Supply Chain Segment	Product/Component	Representative Northern Appalachian Assets
Raw Materials	Silicon	Ferroglobe
Refined Materials	Manganese	Eramet; Felman Production
	Graphite	Amsted Graphite Materials; SGL Carbon
Subcomponents	Electrode Coatings	PPG; Chemours
End Products	Cells	Ultium Cells (GM/LG)
	EV Powertrains	Höganäs; Carpenter Technology, Toyota
	Energy Storage Systems (ESS) Packages	Mitsubishi Electric Power Products
	ESS Thermal Management	Amphenol
End of Life	Metals	INMETCO; Li-Cycle
	Second-life reuse	Parthian Battery Solutions

Source: Study Team

5. Framework to Capture Market Share

This section covers approaches that can be taken by stakeholders to promote and improve the energy storage industry in Northern Appalachia.

5.1 Cluster Development Frameworks

Technological innovation drives job creation. Experts estimate that for each new high-tech job created, five additional jobs are created outside the high-tech sector.[161] Technology innovation has the largest multiplier of all industries — three times higher than manufacturing. High-tech jobs also offer higher salaries. For these reasons, state economic development groups invest significant resources into technology innovation clusters. They recognize the interaction between technology innovation and local standard of living, and because of this make innovation a priority.[162]

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[160] *See* https://vantageventures.io/vantage-spotlight-on-auggie-chico-of-parthian-battery-solutions. *See also* https://www.mdpi.com/1996-1073/14/8/2217
[161] Moretti, E. (2012). *The New Geography of Jobs. Moretti, E. (2012). The New Geography of Jobs.* Houghton Mifflin Harcourt: New York, NY.
[162] *Id.*

In developing a roadmap for energy storage industry development in Northern Appalachia, we consider what strategies economic development experts have found to be effective. In 2013, the National Academy of Sciences published the *Best Practices in State and Regional Initiatives: Competing in the 21st Century.*[163] The publication was supported by grants from the DOE, the National Institutes of Health, the National Institute of Standards and Technology, and the Economic Development Administration. It identified several elements of successful cluster development:

- *Investment of substantial public funds* by the states over a substantial period of time, along with the development of intermediating institutions, provides the foundation for progress. These investments also often have a catalytic effect, attracting private investments as well as support from foundations and the federal government.

- *Sustained support by states for educational institutions* can be important for long-term economic development. These institutions provide the research facilities, a trained workforce, a flow of ideas for commercial development, and the branding that characterize successful regions.

- *Community colleges* play an essential role in providing a trained workforce able to adapt to changing technologies and to enable new opportunities for people who want to enter new professions as the local economy evolves.

- *Public-private partnerships* facilitate the collaboration needed to develop the necessary workforce, provide and enrich research facilities and agendas, help develop new ideas, and support bringing the resulting products to the market.

- *Funding from philanthropic foundations* can play a significant and often catalytic role in initiating, complementing and sustaining action by regional and state authorities.[164]

The Academy identified research institutions as particularly important to innovation-based regional economic development and as “the cornerstone of U.S. international competitiveness.”[165] University faculty recruitment, including the creation of endowed chairs, has emerged as an important tool for innovation-based economic development. Additionally, research institutions that own, operate, and share laboratories and state-of-the-art equipment with the private sector can enable cluster development. Cooperative research among universities and private companies is especially critical to fostering innovation.[166]

The Academy also identified the culture of entrepreneurship as critical to cluster development. This culture includes readily available funding from angel investors and early-stage finance companies. It also includes local economic development organizations and philanthropies that

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[163] *Supra, fn.* 72.
[164] *Id.*
[165] *Id.*
[166] *Id.*

encourage regional innovation, such as through SBIR grant application support. Finally, policy continuity and stable political leadership are important to the development of a healthy entrepreneurship culture.

5.2 Industry Development Strategies and Recommendations

Below are recommendations for policymakers and stakeholders interested in seeing the energy storage industry grow in Northern Appalachia.

5.2.1 Strategies Identified in State and Federal Energy Storage Roadmaps

In developing its recommendations, the Study Team specifically considered critical goals and key actions set forth in the DOE 2021 *National Blueprint for Lithium Batteries*.[167] Meant to address the challenge to *Innovate Here, Make Here,* and *Deploy Everywhere* as outlined in the DOE's Energy Storage Grand Challenge Roadmap,[168] these goals and actions will "help guide investments to develop a domestic [energy storage] manufacturing value chain."[169]

The DOE's vision is that by 2030 the United States and its partners will establish a secure battery materials and technology supply chain that supports long-term U.S. economic competitiveness and equitable job creation, enables decarbonization, advances social justice, and meets national security requirements.

Goals to enable the U.S. in realizing this vision include the following:

- Secure U.S. access to raw materials for lithium batteries.

- Establish a program to increase domestic processing and production of critical battery materials; establish a Research, Development, Demonstration & Deployment (RDD&D) program to discover and produce alternatives for critical battery materials.

- Implement policies and support that enable the expansion of U.S. lithium-battery manufacturing, including electrodes, cell, and pack production.

- Establish and support U.S. industry to implement a secure domestic lithium-battery recycling ecosystem that enables a U.S.-based circular materials supply chain.

- Support research, development, and demonstration from academic institutions, national laboratories, and U.S.-based industries into all aspects of the lithium-battery supply chain for commercial and defense applications.

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[167] https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries
[168] https://www.energy.gov/sites/default/files/2020/12/f81/Energy%20Storage%20Grand%20Challenge%20Roadmap.pdf
[169] *Id.*

- Support development of a trained battery supply chain workforce that promotes career transition and equitable access through programs in trade schools, community colleges, and public universities.

- Determine new approaches to create and implement public-private partnerships to encourage private investments and ensure alignment with DOE's national blueprint.

Recent state plans also bolster the framework that guides the adoption of energy storage technology. For example, the Public Utility Commission of Ohio's *Roadmap to Ohio's Energy Future* "encourages Ohio's EDUs to actively pursue the potential benefits energy storage can provide to the distribution grid and Ohio ratepayers."[170] Pennsylvania has released a plan called the *Pennsylvania Energy Storage Assessment* that includes recommendations to "encourage the growth of Pennsylvania's energy storage industry, enhance resilience, and provide environmental benefits, while balancing costs and economic equity concerns."[171] While West Virginia does not yet have its own state-level plan for energy storage, West Virginia University has recently released a report—*West Virginia's Energy Future*—outlining how the state can reach a stationary storage capacity of 5,000 megawatts by 2040.[172] This plan aims for generating nearly 5,000 megawatts of energy storage installations through 2040.

5.2.2 State-Level Policies for Fostering Regional Markets

Goals like those mentioned above will require policy changes at the state level in addition to those implemented by the federal government. This section provides state-level policy recommendations for growing the energy storage industry in Northern Appalachia and helping to achieve U.S. competitiveness in this sector.

5.2.2.1 Grid/Stationary Storage Strategies

One of the most important strategies for enabling energy storage adoption in stationary power settings is the adoption of rules that enable microgrid development. Microgrids are "islandable" grids that rely on distributed generation and energy storage to ensure local power is not interrupted during general grid disturbances (*see* Figure 23). Many commercial end users require enhanced uptime over that provided by the traditional grid. This has become particularly important as we move toward the digital economy, where the internet-of-things (IoT) mandate nearly 100% uptime. Advanced manufacturing, for instance, is experiencing a convergence of

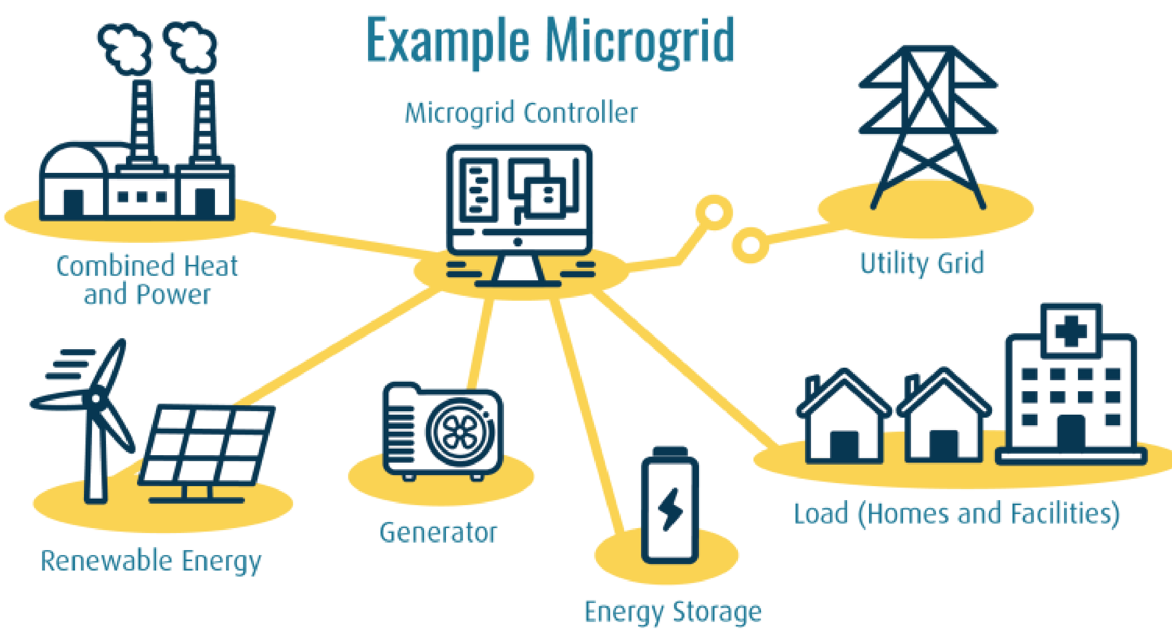
[170] "PowerForward Ohio: A Roadmap to Ohio's Energy Future," Public Utilities Commission of Ohio, Available Online: https://puco.ohio.gov/wps/wcm/connect/gov/38550a6d-78f5-4a9d-96e4-d2693f0920de/PUCO+Roadmap.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_M1HGGIK0N0JO00QO9DDDDM3000-38550a6d-78f5-4a9d-96e4-d2693f0920de-nawqRqj

[171] Burgess, Edward, et al, "Pennsylvania Energy Storage Assessment," Pennsylvania Department of Environmental Protection, prepared by Strategen Consulting, LLC, April 2021, Available Online: https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/EnergyAssurance/Strategen_PA_Energy_Storage_Assessment_April_2021.pdf

[172] "West Virginia's Energy Future: Built Back Better," West Virginia University Law Center for Energy and Sustainable Development, 2021, Available Online: https://energy.law.wvu.edu/files/d/3ba79f26-3d25-4c5e-a016-b7966c092ff7/wvef-built-back-better-2021.pdf

operating and information technologies, leading to an increasing need for system resiliency. Energy storage is at the heart of a resilient microgrid, and end users who need resiliency will pay a premium for such power.

Figure 23. Example of Energy Storage Within a Microgrid



Source: National Association of State Energy Officials[173]

Notwithstanding this need for resilient systems, current laws in most states – including Ohio, Pennsylvania and West Virginia – prevent microgrids from being built anywhere except on single-owner campuses, such as universities and military bases. Utilities who build microgrids are required to socialize the cost across the rate base, and there is little chance of public utility commissions agreeing to this, since it would mean cross subsidization of ratepayers. State legislators and utility regulators will need to create special tariffs for microgrids. Alternatively, or additionally, legislators and regulators must allow multi-customer systems to be built that can deploy microgrids, including energy storage systems.

In addition to microgrid adoption, below are some recommendations identified in the DOE's 2020 *Energy Storage Handbook* that could specifically enable development of stationary energy storage.[174] Figure 24 illustrates grid-connected energy storage projects within the study region that are operational. DOE's recommendations highlight ways to go about growing this regional market.

[173] https://www.naseo.org/issues/electricity/microgrids
[174] *See* https://www.sandia.gov/ess/publications/doe-oe-resources/eshb

- *Procurement Mandates.* Procurement targets are mandates set by a state that require regulated utilities to acquire a specified quantity of energy storage by a designated deadline. The fundamental purpose of a procurement mandate is to provide more opportunities for energy storage and stimulate market growth in a specific state.

- *Financial Incentives, Subsidies, and Tax Credits.* Regulatory frameworks typically prevent utilities and customers from being able to monetize the value of energy storage. Incentives provided at the state level can serve as a bridge to jumpstart a market while regulatory policies are finalized. The prevailing industry perception is that the cost of batteries is still too high for most grid applications to be viable, other than where local regulations provide incentives for deployment.

- *Utility Ownership of Energy Storage Assets.* Energy storage is typically classified as a generation asset, meaning that utilities in states with deregulated electricity markets such as Ohio and Pennsylvania are prohibited from owning it.[175] Developing a comprehensive regulatory framework for energy storage within the wider electricity regulatory framework, specifying the limited conditions under which utilities can own and operate distributed storage, could provide opportunities to optimize the distribution system and enhance its flexibility in using more cost-effective resources.

- *Inclusion of Energy Storage in Long-Term Resource Planning.* Like most states, Ohio, Pennsylvania, and West Virginia require utilities to submit long-term resource plans to the state public utilities commission for approval. These plans demonstrate a utility's ability to reliably meet long-term demand projections using a combination of generation, transmission and energy efficiency investments. Unfortunately, because traditional planning models do not consider many of the services that energy storage can provide, the technology does not fit neatly into traditional planning processes.

- *Changes to Net Energy Metering Policies.* Net energy metering (NEM) is a state-level program that is intended to promote direct customer investment in renewable energy by compensating the customer for excess energy that is generated at the customer's location but sold back to the utility at current retail rates. NEM programs can vary greatly state to state, and typical variations across states may include the types of technologies that are eligible to participate in the state's NEM and the customer classes that can participate.

  Pairing renewable-generation-plus-storage with NEM has received minimal policy attention to date due to low level deployments of energy storage in most states. Allowing this sort of pairing to qualify for NEM could help ensure that renewable generation projects such as solar "pencil out."

- *Changes to Renewable Portfolio Standard Programs.* A state renewable portfolio standard (RPS) has arguably been the single most important state policy mechanism for

[175] *See* https://www.epa.gov/repowertoolbox/understanding-electricity-market-frameworks-policies

advancing clean energy over the last two decades. In the absence of a federal mandate for renewable generation, RPS programs are among the most prominent clean energy policies in the U.S. today. Allowing energy storage to be eligible for state RPS programs could provide numerous benefits, including: helping to shift renewable generation to better match peak loads; reducing the need for peaking and backup generators on the grid; and reducing customer demand charges.

- *Multiple Use Applications.* One of the more commonly cited barriers to the deployment of energy storage is the inability to quantify and capture the multiple value streams that energy storage can provide to the grid. Before the advent of deregulated electricity markets, valuation of storage usually only considered the ability of storage to provide two basic classes of services: capacity and "load leveling" (i.e., charging storage with low-cost off-peak generation and displacing high cost on-peak energy). Other benefits such as ancillary services were rarely valued.

  The unique characteristics of energy storage (both load and supply) create flexibility to provide multiple uses or applications, sometimes simultaneously, and therefore layer on more than one revenue stream. Unfortunately, the array of potential services for which energy storage is ideally suited is not well understood at the present time. Developing a regulatory framework around energy storage that is flexible enough to allow for complex, multiple-use applications ensures that the technology is properly valued and allows it to achieve its full economic potential.

- *Cost-Benefit Analysis (Valuation) Tool.* The deployment of energy storage is dependent on the economic benefits that can be obtained either in a traditionally regulated or restructured market. Unfortunately, current market structures and policies lack clear mechanisms to identify and capture the full value of an energy storage system (ESS).

  The purpose of a cost-benefit analysis tool is to understand whether or not a specific investment is desirable. The net benefits of each alternative resource, whether it is a distributed energy resource or a traditional generator resource, can be represented using a common metric of dollars. As long as all the cost and benefit categories, including the external costs and benefits, are consistently calculated for each resource, comparing the net benefits of each alternative and choosing the one that yields the highest net benefit to society will ensure that only socially beneficial ESSs are installed.

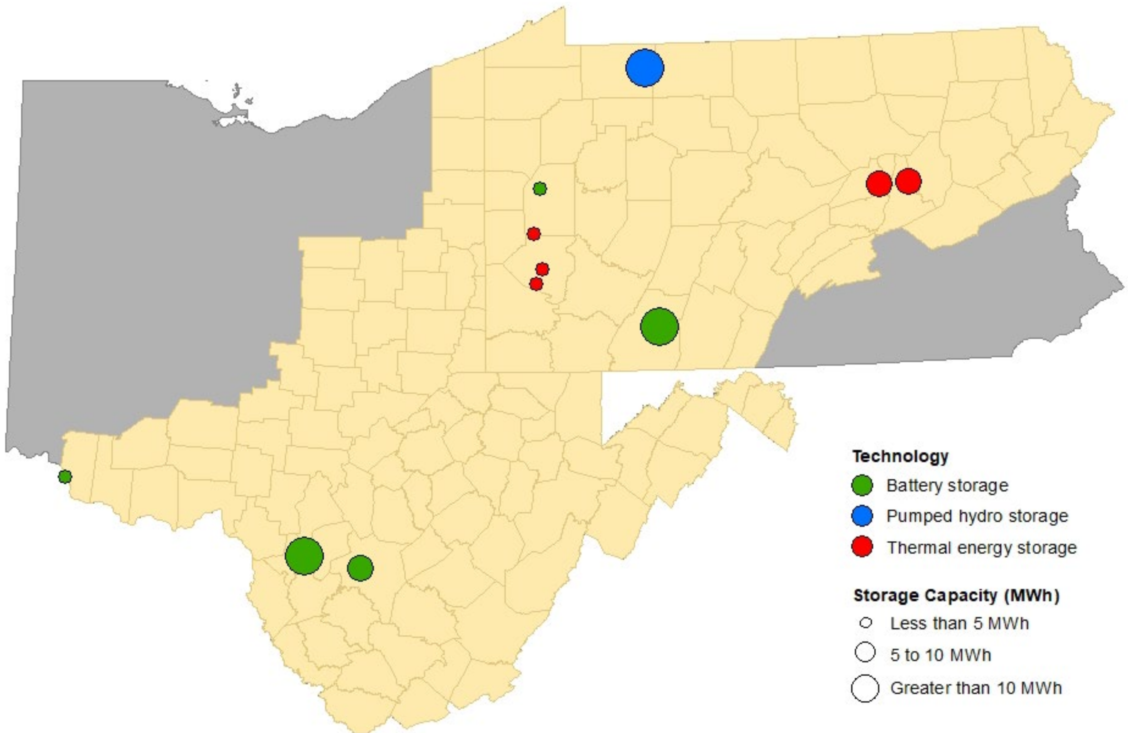
- *Distribution System Modeling.* Due to the inherent diversity of its physical and electrical characteristics, energy storage can be utilized in many different locations across the electric power system. Much of the new storage that is expected to come online over the next decade is expected to be connected to distribution feeders. In addition, the increasing adoption of all forms of distributed power generation is altering the nature and profile of loads on distribution grids and stretching the hosting capacity among certain distribution lines. Distribution planners currently lack tools and methods to assess storage impact on system capacity, reliability, and power quality. The result is that there has been a lack of adequate planning.

Distribution planning for energy storage typically includes assessment of hosting capacity, forecasting, and locational benefits of specific distribution lines. Requiring utilities to file distribution resource plan proposals that identify optimal locations for the deployment of distributed resources such as energy storage and renewable generation resources supports optimal ESS sizing, placement, and operation.

- *Changes to Interconnection Standards.* Interconnection procedures are the rules of the road for the electric distribution grid. Without common rules and predictable processes, gridlock and costly projects can result. However, interconnection standards that were developed without consideration of widespread renewables and/or energy storage are likely in need of significant revision. This creates a barrier for energy storage deployment, as without permission to interconnect an ESS has no access to the market.

  The inadequacy of conventional interconnection standards has created a barrier for energy storage simply due to the fact that it has created uncertainty about how energy storage should be treated at a localized level, thus resulting in market inertia and delays in permitting. Modernizing interconnection standards to reduce uncertainty about how energy storage should be treated locally can enable cost-effective, high-efficiency clean energy projects and the energy storage that supports them.

Figure 24. Operational Grid-Connected Energy Storage Projects



Data Source: DOE Global Energy Storage Database[176]

5.2.2.2 Transportation-Related Storage Strategies

Below are recommended policies from the International Energy Agency to promote transportation-related storage.[177]

- *ZEV mandate (sales requirements)* Many states have mandates for companies with sales of a certain number of vehicles to sell a certain number of zero-emission vehicles as a percentage of their total sales. For instance, the state of California currently requires manufacturers with annual sales between 4,501 and 60,000 vehicles to sell 14.5% or more of their vehicles as zero-emission vehicles or purchase credits to make up for them.[178] This number is set to increase to 22% by 2025.

- *Fuel economy standards (limit CO_2 per mile)* According to the Energy Policy Institute at the University of Chicago, "fuel economy standards are the United States' cornerstone

[176] "DOE Global Energy Storage Database," Sandia National Laboratories, 2021, Available Online: https://sandia.gov/ess-ssl/gesdb/public/

[177] https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment

[178] "Zero Emission Vehicle (ZEV) Production Requirements," State, Laws & Incentives, AFDC, EERE, US Department of Energy, Available Online: https://afdc.energy.gov/laws/4249

transportation policy aimed at reducing both oil consumption and greenhouse gas emissions." They are controversial, however, with the volatility of gasoline prices threatening the efficiency of the policy as a tool for reducing emissions. Standards will, however, have an impact on the attractiveness of electric vehicles and thus the importance of development of a market for energy storage technologies.

- *Heavy-duty ZEV weight exemptions* Some states allow ZEV trucks to exceed strict weight restrictions by a set amount, especially since batteries weigh more than diesel fuel combustion technologies. These can serve as an impetus for manufacture and sale of zero-emission vehicles by removing a barrier to their use. California allows zero-emission and near zero-emission vehicles to exceed weight limits for vehicles up to 2,000 pounds.[179]

- *Vehicle purchase direct incentives* Direct incentives are a tool for encouraging buyers to purchase vehicles that conform to a certain design or specification. Direct incentives for vehicles that use energy storage technology can be valuable for the energy storage industry since they could spur demand for vehicles that use energy storage technologies.

- *Develop hardware standards and building regulations for vehicle charging equipment* In order for people to be comfortable using vehicles that use energy storage technologies, they will need to know they can power their vehicles when they need to. Hardware standards and building regulations could spur the growth and development of an energy storage infrastructure, which would make adoption of vehicles that use energy storage technology easier. This will be especially important if there are many players in the energy storage industry: making sure that different technologies work together will make it so there is no duplication of infrastructure, thus reducing costs for growth of the industry.

- *Direct incentives for charging equipment and supporting infrastructure, including to utilities* Another approach to improving infrastructure is subsidizing it. Subsidies that come through state government or utilities could spur the growth of the energy storage industry by making it more viable to drive cars because they are easier to refuel.

5.2.3. Additional strategies for regional industry development

Given the current assets that exist in Northern Appalachia and the market trends for energy storage, the following are strategies that could be adopted to further the energy storage cluster.

5.2.3.1. Development of a culture of entrepreneurship.

These strategies could help maintain or materially improve the culture of entrepreneurship in Northern Appalachia as it relates to energy storage:

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[179] "Zero Emission Vehicle (ZEV) and Near-ZEV Weight Exemption," State, Laws & Incentives, AFDC, EERE, US Department of Energy, Available Online: https://afdc.energy.gov/laws/12069

- Fund Market Validation Program for Energy Storage Startups.

  One of the most perilous obstacles that entrepreneurs face as they bring new technology to market has been dubbed the "Technological Valley of Death."[180] This is the stage where entrepreneurs must demonstrate the market validity of their technologies to prove to investors that they are viable beyond the laboratory.[181] A review of energy incubators and accelerators shows that many of them offer services such as help with developing a business plan, one-on-one mentoring, access to testing equipment, investor connections, and funding for prototype development.[182]

  What energy-related startups are missing, however, is a formal market validation program to determine the actual need for their product within a target market. This process validates the business idea and demonstrates to investors that sufficient demand exists for the technology to warrant continued funding, increasing the likelihood of a successfully commercialized product. As outlined by Harvard Business School, market validation involves 5 steps:

  - Clarifying business goals and customer assumptions. This includes creating an effective value proposition, defining the target audience and the entrepreneur's assumptions about them, and identifying what differentiates the new product from existing ones;
  - Assessing target market size and the share of it that could potentially be captured;
  - Researching the monthly search volume of terms related to the product and to the startup's mission. When consumers need a product or service, they often use a search engine to see what the market has to offer;
  - Conducting customer validation interviews. This can include focus groups, surveys, and one-on-one interviews, where potential customers are asked about their motivations, preferences, needs, and the products they currently use;
  - Testing the new product. If there is space in the market for the new product, it should undergo alpha and beta testing under real-world conditions. In the case of beta testing, this involves testing by a limited group of real, external users who are specifically told to identify problems.[183]

- *Obtain JobsOhio R&D grant.* The JobsOhio R&D grant program was created to facilitate new strategic corporate R&D centers in Ohio. Energy storage is expressly included among the industries contemplated. A center must be a newly created (or repurposed) physical space dedicated to technology innovation.[184] Total initial funding available for this program is $100 million. It requires an investment of at least $3 million from a corporation.

[180] https://www.energy.gov/eere/buildings/technology-market
[181] https://s3.us-east-2.amazonaws.com/uploads.thebreakthrough.org/legacy/blog/Valleys_of_Death.pdf
[182] *See* https://www.rit.edu/incubator. *See also* https://incubator.pgworks.com/
[183] https://online.hbs.edu/blog/post/market-validation
[184] JobsOhio. (n.d.). "JobsOhio Research & Development (R&D) Center Grant." https://jobsohio.com/why-ohio/incentives/jobsohio-loan-and-grant-programs/jobsohio-research-and-development-grant/

Applicants must have a five-year operating history and annual revenue of greater than $10 million. Because JobsOhio is looking for a company with a pre-existing critical mass, the best candidates for this might be Northern Appalachia's system integrators.

- *Increase available seed or early-stage capital funding*. Additional state or philanthropic funding for venture capital organizations would significantly help local entrepreneurship.

- *Develop and fund incubators.* Incubators can encourage entrepreneurship in a region. The role of an incubator is to increase the chances of success for young firms by making entrepreneurial activity less risky. This type of business support program provides services that help startups grow, including the following:

    - Coworking space, conference rooms, and private offices.
    - Specialized equipment (e.g., technical/testing facilities).
    - Funding through angel investors and venture capital.
    - Networking and collaboration opportunities.
    - Business skills training (e.g., in accounting).
    - Mentorship, either directly or by connecting clients/tenants to external parties (individuals or mature companies) with industry expertise and business and fundraising experience.

    An energy incubator faces a unique challenge in connecting young companies to adequate funding due to some of the high costs associated with energy storage development. On the other hand, energy storage is a safer bet compared to other early-stage investment opportunities (e.g., computer software) that often have more uncertain product development life cycles and less pervasive demand.

    The Opportunity Zones program created through the Tax Cuts and Jobs Act of 2017 could provide a deeper pool of funds needed to finance energy storage startups. (Bi-partisan legislation was introduced in April 2022 in both houses of Congress to extend the Opportunity Zone incentive program for two years beyond its original term.)[185] The program is designed to encourage investment in census tracts designated as economically distressed by the U.S. Treasury by providing federal tax incentives to invest in *Qualified Opportunity Funds* (QOFs), which, in turn, invest directly or indirectly in these "Opportunity Zones."

    According to the Economic Innovation Group, Ohio, Pennsylvania, and West Virginia have 675 opportunity zones, many of which are located in Northern Appalachian counties.[186] The National Council of State Housing Agencies' Opportunity Zone Fund Directory shows that as of February 2022, there were 20 qualified opportunity funds in Ohio, Pennsylvania,

[185] *See* https://www.booker.senate.gov/news/press/booker-scott-kind-kelly-introduce-bipartisan-bicameral-bill-reforming-opportunity-zones
[186] "Opportunity Zones," Economic Innovation Group, Available Online: https://eig.org/opportunityzones/facts-and-figures

and West Virginia with a combined fund size maximum of nearly $2.2 billion.[187] Energy storage companies could potentially take advantage of these funds, which target a mixture of economic development, community development, small business development and renewable energy investment.[162] The establishment of a Northern Appalachian Energy Storage/Clean Energy Technology opportunity fund could be a useful source of financing for early-stage energy storage business support.

- *Develop Centers of Excellence.* "Center of Excellence" is a term commonly used by federal grantors and emphasized in federal grantmaking. If a university or other center in Pittsburgh or another area in Northern Appalachia aimed to configure themselves as a hub for energy storage, it could be eligible for federal funding that it would otherwise have trouble accessing.

5.2.3.2. Programs that spur project investment in and deployment of energy storage technology.

Often the best way to develop a regional industry is to incentivize local deployment of technology developed by companies operating within the industry. The following are strategies for enabling deployment through local adoption of energy storage technologies:

- *Develop Green Banks and Revolving Loan Funds.* The Appalachian Regional Commission invests in grants to states and local development districts to support loans that can be used to develop energy storage clusters. Local districts can tap into these funds by demonstrating jobs will be created.[188] More robust local markets for renewable power might enable local energy storage companies to increase deployment of their technologies. Green Banks can spur development of renewable power, and thereby trigger more demand for storage. According to the U.S. Energy Information Administration, Ohio, Pennsylvania, and West Virginia all have lower energy costs than the national average, with retailers paying 9.4, 9.7, and 8.9 cents per kilowatt-hour respectively in these states compared to the national average of 10.6 centers per kilowatt-hour.[189] This makes renewable power more difficult to finance since competition for competitive prices is fierce. Green banks make funding available to support loans for renewable energy projects through guarantees and gap financing. Connecticut has a successful green bank model.[190] Cuyahoga County's Office of Sustainability and the Cleveland Foundation are collaboratively developing a similar program in Northeast Ohio.[164]

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[187] "Opportunity Zone Fund Directory," National Council of State Housing Agencies, 2022, Available Online: https://www.ncsha.org/resource/opportunity-zone-fund-directory/.
[188] https://www.arc.gov/wp-content/uploads/2020/07/RLF-Guidelines-2020.pdf
[189] "State Electricity Profiles," Electricity, U.S. Energy Information Administration, November 4, 2021, Available Online: https://www.eia.gov/electricity/state/
[190] For more information on green banks and facilitating investment into domestic low-carbon, climate-resilient infrastructure, visit the Green Bank Network homepage at https://greenbanknetwork.org

5.2.3.3. Develop regulations that encourage energy storage deployment.

Ohio, Pennsylvania, and West Virginia are deregulated electricity market states, meaning that generation markets are competitive, but distribution remains fully regulated. Energy storage can be valuable on either side — as support for generation or for distribution. In either case, regulatory frameworks can be developed or maintained to encourage a rapid deployment of energy storage technologies in Northern Appalachia. This includes the following:

- Design electric vehicle (EV) rates and infrastructure to encourage EVs. Adoption of energy storage technology at the consumer level will be driven by the electric vehicle market. In order for electric vehicles to see widespread adoption in Northern Appalachia, regulators in Ohio, Pennsylvania, and West Virginia will need to create a regulatory framework that sets rates at a competitive price for consumers and producers and facilitate the construction of infrastructure throughout the region to support charging of vehicles.

5.2.3.4. Other Strategies

Below are other strategies that policymakers can use to promote the energy storage industry in Northern Appalachia.

- *Recruitment/Retention of energy storage faculty and researchers*. Technology-intensive companies tend to locate near the best universities in certain fields of science and engineering to enable their internal research departments to work with "star" scientists and recruit promising students. Additionally, startup companies spun off from universities often establish operations near these institutions. A key driver in perpetuating this virtuous cycle is the attraction of top academic talent to a given institution and within regional startup communities. Cluster-inducing activities for energy storage could include leveraging academic and tech R&D programs to endow energy storage-specific faculty chair positions in Northern Appalachian universities to be filled by eminent researcher-entrepreneurs recruited from throughout the country who could bring skilled research staff and scientists with them.

- *Build Organizational structure.* A successful regional energy storage industry could require a formal organization to take leadership, enable communication and collaboration, and identify opportunities for regional industry growth.

- *Promote Energy Storage Association and other trade organizations.* Energy storage is critical to a broad range of industries in Northern Appalachia. However, trade and engineering associations from different industries often do not communicate well with one another. Organizations that provide more general technical networking opportunities could be a clearinghouse for cross-industry collaboration that helps connect new industries that depend on energy storage industry growth.

5.3 Role of Social Justice, Decarbonization, and National Security in Energy Storage Strategies for Northern Appalachia

In addition to promoting the growth of the energy storage industry in Northern Appalachia, the recommendations described previously will have implications for social justice, international efforts at decarbonization, and national security. In this section, we address these implications, a fuller discussion around which appears in Appendix D. The Appalachian Regional Commission has further identified inclusion as one of its five principal goals.[191]

5.3.1. Procurements Mandates and Social Justice, Decarbonization, & National Security

In a monopolistic economic environment like that held by electricity distribution companies, mandates could pose social justice concerns, since they can easily pass costs on to ratepayers. From a decarbonization standpoint, procurement mandates would make low-carbon energy sources more viable; states requiring the purchase of energy storage capacity will likely make it easier for wind, solar, and other low-carbon intermittent energy sources to replace higher-carbon uses of energy. Energy procurement mandates could have mixed impacts on national security as large, centralized storage could become a new target for agents working to destabilize the U.S. economy.

5.3.2. Government Financial Incentives and Social Justice, Decarbonization, & National Security

Subsidies for energy storage have social justice implications. States can combine subsidies with required qualifications for hiring practices or deployment that can further social justice goals. Subsidies can also encourage decarbonization by tying the rate and availability of incentives for energy storage to reductions in greenhouse gas emissions. Creating a tax credit for standalone battery storage could also reduce reliance on foreign supply chains and manufacturing and meet a growing military need for reliable battery technology, bolstering national security prospects.

5.3.3. Utility Ownership of Energy Storage Assets and Social Justice, Decarbonization, & National Security

Distributed ownership, community ownership, and co-ownership of energy storage assets promotes social justice. While utility ownership of energy storage assets seems like a natural approach to decarbonizing large-scale energy systems, decarbonization has also happened in decentralized energy storage settings.[192] However, utility ownership of energy storage assets can enable rapid deployment of renewable energy sources at scale, thus being an asset for national security.

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[191] https://www.arc.gov/wp-content/uploads/2021/09/Building-Community-Leaders-and-Capacity.pdf
[192] Shen, Bo, Fredrich Kahrl, and Andrew J. Satchwell. "Facilitating Power Grid Decarbonization with Distributed Energy Resources: Lessons from the United States." Annual Review of Environment and Resources 46 (2021): 349-375.

5.3.4. Energy Storage, Long-term Resource Planning, and Social Justice, Decarbonization, & National Security

Long-term resource planning is fundamentally an approach that advances social justice concerns since a key characteristic of the process is public participation, which brings different perspectives to the decision-making process.[193] Since energy storage deployment is necessary for widespread adoption of renewable energy sources, factoring energy storage into long-term resource planning can advance decarbonization goals as well. National security considerations may be murkier; in an age of manufactured democratic participation, this particular process may include people who do not have the public's interests at heart.

5.3.5. Changes to Net Energy Metering Policies and Social Justice, Decarbonization, & National Security

Pairing storage technologies with net metering may cause some social justice concerns as a core problem with combining this technology with this policy is how to make the combination fair for all parties involved.[194] However, creating net energy metering policies that encourage adoption of renewable generation could enhance decarbonization. Creating a regulatory environment that encourages the adoption of renewable generation could also make small-scale, local-level energy storage more prevalent; this decentralization could make it harder for those looking to threaten national security to destabilize the electrical grid.

5.3.6. Changes to Renewable Portfolio Standard Programs and Social Justice, Decarbonization, & National Security

Renewable portfolio standards increase prices by requiring adoption of power generation technologies that are more expensive.[195] At the same time, they create benefits in the form of improved health from reduction in air pollution and reduction in climate change damages. The relative magnitude of these impacts is a key consideration when assessing the social justice impact of renewable portfolio standards.

By definition, renewable portfolio standards promote decarbonization as requirements to reduce use of non-renewables reduces the amount of carbon emitted into the atmosphere. Further, renewable portfolio standards could promote national security by reducing U.S. reliance on non-renewables from other countries.[196]

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[193] Hirst, Eric, and Charles Goldman. "Creating the future: integrated resource planning for electric utilities." *Annual review of energy and the environment* 16, no. 1 (1991): 91-121.
[194] Mow, Benjamin, "The Solar Energy Trifecta: Solar + Storage + Net Metering," State, Local, and Tribal Governments Blog, NREL, February 12, 2018.
[195] Wiser, Ryan, Trieu Mai, Dev Millstein, Galen Barbose, Lori Bird, Jenny Heeter, David Keyser, Venkat Krishnan, and Jordan Macknick. "Assessing the costs and benefits of US renewable portfolio standards." Environmental Research Letters 12, no. 9 (2017): 094023.
[196] Endrud, Nathan E. "State renewable portfolio standards: Their continued validity and relevance in light of the dormant commerce clause, the supremacy clause, and possible federal legislation." Harv. J. on Legis. 45 (2008): 259.

5.3.7. Multiple Use Applications and Social Justice, Decarbonization, & National Security

Since energy regulation is at its heart about allowing a market to exist without creating an exploitative environment, making sure energy storage is not a backdoor to exploitation is a key social justice concern.

Allowing for multiple use can be key to supporting decarbonization as there will be more opportunities for the grid to use stored energy from renewable sources, thus lessening reliance on carbon-intensive power generation. Allowing for varied use of energy storage has clear national security implications; deploying energy storage at different points on the grid will improve grid-scale resilience and reliability, making the grid less vulnerable to actors that may destabilize it.

5.3.8. Cost-Benefit Analysis (Valuation) and Social Justice, Decarbonization, & National Security

By conducting cost-benefit analysis of regulatory decisions, regulators can understand how a given policy impacts different stakeholders, which is key to understanding the social justice implications of a policy change. Cost-benefit analysis can also be valuable in understanding how decarbonization interacts with policy impacts by fully weighing the societal and economic costs against the benefits. Cost-benefit analysis, when combined with risk analysis, can also be valuable for analyzing the national security implications of policy change by assigning probabilistic weights to outcomes and assessing the costs associated with different scenarios.

5.3.9. Distribution System Modeling and Social Justice, Decarbonization, & National Security

Distribution resource plans can be used to promote social justice by including equity criteria in defining optimal solutions. Decarbonization can also be included as a criterion, with utilities giving greater weight to locations that shift energy usage away from carbon-intensive power sources. Likewise, national security can be rolled into distribution system modeling; utilities can follow guidance from security experts to improve grid reliability and resilience to make it able to withstand unexpected shocks.

5.3.10. Changes to Interconnection Standards and Social Justice, Decarbonization, & National Security

Interconnection standards that incorporate energy storage can also promote social justice.
Service areas more prone to reliability issues often correspond to areas with more low-income residents. By building energy storage into interconnection standards and introducing an equity dimension, low-income residents can realize more reliable power.

A change to interconnection standards can also help facilitate decarbonization. Since energy storage encourages the use of renewable energy sources, factoring it into interconnection standards can facilitate a reduction in carbon emissions.

Interconnection standards are also likely to have national security implications. Energy storage can be a tool for promoting grid reliability and resilience, which is key to promoting national security interests.

5.3.11. ZEV mandate (sales requirements) and Social Justice, Decarbonization, & National Security

Zero emission vehicle (ZEV) mandates pose some concerns from a social justice perspective, in particular how to keep prices for goods affordable for people with fewer resources. However, ZEV mandates will likely promote decarbonization by encouraging people to move away from the use of gasoline and diesel. (This will only work, however, if electricity is generated using low- or zero-carbon technology.) From a national security perspective, ZEV mandates could be useful by reducing reliance on petroleum from countries whose policies run counter to U.S. interests.

5.3.12. Fuel Economy Standards and Social Justice, Decarbonization, & National Security

If fuel economy standards have an impact on the type of cars that are manufactured and sold, this could initially make the general passenger vehicle stock more expensive for consumers, which would likely hit low-income consumers the hardest, a concern from a social justice perspective. However, fuel economy standards would allow consumers to go further on less gas, leading to less use of fossil fuels and thus facilitate decarbonization. Fuel economy standards may also facilitate the development of higher fuel economy vehicles, which could be valuable from a national security perspective by reducing demand for petroleum products from countries with an adversarial relationship to the U.S.

5.3.13. Weight Exemptions for Heavy-Duty ZEVs and Social Justice, Decarbonization, & National Security

Allowing heavy-duty ZEVs to be exempted from weight restrictions could have social justice implications by subsidizing the wear and tear of roads from heavy-duty ZEV use, diverting public funding away from social programs. However, more zero-emissions vehicles on the road would clearly support decarbonization goals.

Deteriorating roads could have some national security implications as they would be harder to use to move equipment and people over, thus making them less useful in a time when resources would need to be mobilized across the country.

5.3.14. Vehicle Purchase Direct Incentives and Social Justice, Decarbonization, & National Security

Direct incentives for ZEV purchases could have social justice implications if only upper-income individuals make these purchases and claim the incentives. However, any such purchases are likely to promote decarbonization. Direct incentives would also likely improve national security prospects on the margins by encouraging the development of vehicles that rely less on fossil fuels from foreign sources.

5.3.15. Hardware Standards, Building Regulations for Vehicle Charging, and Social Justice, Decarbonization, & National Security

Ensuring vehicle charging equipment meets certain hardware standards and building regulations is a way to protect public safety, particularly for disadvantaged groups more likely to be hurt by weak standards, an obvious social just concern.

Onerous standards and regulations, though, could undermine decarbonization efforts. Standards and regulations have played a key role, for instance, in the slowdown of the United States nuclear energy industry. If standards and regulations are too difficult to navigate, it will be harder for vehicle charging equipment to be installed and it will slow efforts to use electric vehicles to encourage decarbonization.

Hardware standards and building regulations could be important for encouraging development of equipment that is both safe and secure (thus less likely to be tampered with and posing fewer national security risks).

5.3.16. Direct Incentives for Charging Equipment and Social Justice, Decarbonization, & National Security

Incentives for charging equipment are likely to benefit upper-income individuals first, causing some social justice concerns in the short run.

These incentives will likely support decarbonization by making it easier for people to use electric vehicles. This will only cause a net decrease in carbon emissions, though, if the power sources used to charge cars are generated from low-emission sources.

Incentives for charging equipment and supporting infrastructure can also bolster national security by creating a system for powering vehicles that is less dependent on petroleum than the current system, thus fostering U.S. energy independence and creating new ways to power military vehicles.

6. Conclusion

Northern Appalachia has both commercial and structural assets that give it the potential to be a leader in energy storage in the future. Among these are the region's relatively low cost of living, its abundance of rural grid networks, and its ecosystem of funders and research institutions supporting innovation in the industry. Northern Appalachia also has many metropolitan areas with strong networks of engineers, a vital ingredient to innovation in this industry. If Northern Appalachia's energy storage industry grows, that would mean more investment and high-income jobs in the region.

Energy storage technologies can be applied in other regional industries in Northern Appalachia. Mining, manufacturing, and farming and forestry are all energy-intensive industries concentrated in Northern Appalachia that could make use of energy storage technologies. Northern Appalachia could also be competitive on the national scale due to its cost and business infrastructure resources.

Companies looking to develop and manufacture energy storage technologies will need to raise financial resources in order to make business plans reality. These could come from partnerships with the DOE or through work with local venture capital funds. The 2021 federal infrastructure bill allocates substantial resources to energy storage efforts and may be a source for financing of energy storage industry efforts in the region.

The project team's analysis of human capital resources in Northern Appalachian metropolitan areas suggests that Northern Appalachia has the technical expertise to be a national or even world leader in energy storage in the 2020s and beyond. Further, the project team finds that Northern Appalachia has strong research and development, commercial, and structural assets that make it competitive as a hub region for energy storage. Marrying these assets together would put Northern Appalachia in a strong position to be a leader in energy storage.

Appendix A. Project Team

Advisory Group & Project Team

The advisory group comprises leading experts in energy storage from the three Northern Appalachian states in the study. Members of the advisory group provided guidance to the project team throughout the research process for the roadmap.

Project Team

Member	**Organization**	**Email Address**
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Advisory Group

Member	**Organization**
Bill Hagstrand	Independent Consultant
Anna Siefken	Carnegie Mellon University
Sam Taylor	West Virginia University
James Wood	West Virginia University

Appendix B: Methodology

An energy storage roadmap for Northern Appalachia that identifies how local assets can be leveraged to capture maximum growth for the region requires that two questions be answered: (1) What are the current assets in the Northern Appalachian region for the energy storage industry, and (2) what can public sector and industry stakeholders do to grow the energy storage industry in the Northern Appalachian region?

The Study Team answered the first question by compiling a list of businesses and institutions in Northern Appalachia in the energy storage or related industries. The team compiled this list from third-party company databases including D&B Hoovers, Mergent Intellect, Reference USA, and the Thomas Register of American Manufacturers. The Study Team queried the following search terms to identify businesses in the industry:

- Anode/Cathode/Electrode
- Electrolyte
- Separator
- Polymer separator/polymer electrolyte
- Polymer manufacturing
- Battery
- Lithium-ion
- Lithium-metal (battery)
- Sodium-metal (battery)
- Lead-acid (battery)
- Flow battery
- Solid state (battery)
- Zinc-nickel (battery)

An advisory committee made up of energy experts from the three states in the region verified this list and provided market and technical guidance, connections to market participants, engagement during development of the work product, and a review of outcomes and recommendations included in the roadmap.[197]

The Study Team drew evidence from national reports on the state of energy storage and trends in the energy storage market to provide context for the regional industry.

The Study Team also conducted semi-structured interviews with Northern Appalachian energy storage industry professionals Anthony Frisone of CZAR-Power, Auggie Chico of Parthian Battery Solutions, and Josh Gould of Duquesne Light (DLC) to provide qualitative context for the roadmap.

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[197] Special thanks to Anna J. Siefken of the Wilton E. Scott Institute for Energy Innovation at Carnegie Mellon University, Samuel Taylor of the West Virginia University Energy Institute, and Bill Hagstrand of the Ohio Fuel Cell Coalition for serving on this committee.

Appendix C: Commercial Energy Storage Assets in Northern Appalachia

Company Name	Location Type	State
6k Additive	Manufacturer	Pennsylvania
AAM Metal Forming	Manufacturer	Pennsylvania
ABB	Manufacturer	West Virginia
Abtrex	Manufacturer	Pennsylvania
Advanced Finishing USA	Manufacturer	Pennsylvania
Advanced Graphite Materials	Manufacturer	West Virginia
Aero Coatings	Manufacturer	Pennsylvania
Ajax TOCCO Magnethermic Corporation	Manufacturer	Ohio
Alcoa Corporation	Corporate Office	Pennsylvania
Aleris	Manufacturer	Ohio
Allegheny Coatings	Manufacturer	Pennsylvania
Almega	Manufacturer	Pennsylvania
Alumnisource	Manufacturer	Pennsylvania
Ameri-Source Specialty Products	Manufacturer	Pennsylvania
American Babbitt Bearing	Manufacturer	West Virginia
American Precision Powder Coating	Manufacturer	Pennsylvania
American Trim	Manufacturer	Pennsylvania
American Zinc Recyling	Manufacturer	Pennsylvania
Amerimax Building Products, Inc	Business Services	Pennsylvania
AMG Resources Corp.	Manufacturer	Pennsylvania
Amphenol Advanced Sensors	Manufacturer	Pennsylvania
Amsted Graphite Materials	Manufacturer	West Virginia
Angstrom Sciences	Manufacturer	Pennsylvania
Anker Industries	Manufacturer	Pennsylvania
Ansys	Business Services	Pennsylvania
APG - Sintered Metals	Manufacturer	Pennsylvania
APG Polytech USA	Manufacturer	West Virginia
APG Sintered Metals	Manufacturer	Pennsylvania
Applied Intellect	Business Services	Pennsylvania
Aquion Energy LLC	Manufacturer	Pennsylvania
ARC Metals Corporation	Supplier	Pennsylvania
Arconic Technology Center	Business Services	Pennsylvania
Arlington Industries	Manufacturer	Pennsylvania
Asap Powder Coating Inc	Manufacturer	Pennsylvania
Asbury Graphite Mills Inc	Manufacturer	Pennsylvania
ASHTA Chemicals	Manufacturer	Ohio
Ati Powder Metals	Manufacturer	Pennsylvania
Axion Power International	Manufacturer	Pennsylvania

Barium & Chemicals Inc	Supplier	Ohio
Batteries Unlimited	Supplier	Ohio
Battery Systems	Supplier	Pennsylvania
Battery Tech LLC	Manufacturer	Pennsylvania
Beaver Valley Alloy	Manufacturer	Pennsylvania
Bedford Reinforced Plastics	Manufacturer	Pennsylvania
Bhayana Brothers	Supplier	Pennsylvania
Cambridge-Lee Industries, LLC	Manufacturer	Pennsylvania
Carnegie Robotics	Manufacturer	Pennsylvania
Carpenter Technology	Manufacturer	West Virginia
Cathode Systems of America	Business Services	Pennsylvania
Cell-Con, Inc.	Manufacturer	Ohio
CenTrak	Corporate Office	Pennsylvania
Cleaveland/Price Inc	Manufacturer	Pennsylvania
Compton Metals Inc.	Manufacturer	Pennsylvania
Comtec Manufacturing Inc	Manufacturer	Pennsylvania
Concast Metal Products Co.	Manufacturer	Pennsylvania
Concurrent Technologies Corporation	Research and Development	Pennsylvania
Continuous Metal Technology	Manufacturer	Pennsylvania
Covestro LLC	Manufacturer	Pennsylvania
Curtiss-Wright	Manufacturer	Pennsylvania
Custom Metal Coating	Manufacturer	Pennsylvania
Cymatics Laboratories Corporation	Manufacturer	Pennsylvania
Datco Manufacturing	Manufacturer	Ohio
Delp Family Powder Coatings	Manufacturer	Pennsylvania
Diamond Electric Mfg. Corp	Manufacturer	West Virginia
Direct Energy Business	Corporate Office	Pennsylvania
Du Pont de Nemours, E. I. & Co.	Manufacturer	Ohio
Du Pont-Washington Works	Manufacturer	West Virginia
Dylan's Coatings	Manufacturer	Pennsylvania
Dynamics Inc.	Manufacturer	Pennsylvania
E.A. Fischione Instruments	Corporate Office	Pennsylvania
East Penn Manufacturing Co	Supplier	Pennsylvania
Eastman Chemical Resins Inc	Manufacturer	Pennsylvania
EC Power	Research and Development	Pennsylvania
Effective Controls Inc	Business Services	Pennsylvania
Eit Corp	Supplier	Pennsylvania
Electrode Blank Materials	Manufacturer	Pennsylvania

Embassy Powdered Metals Inc	Manufacturer	Pennsylvania
Ener Sys	Supplier	Pennsylvania
Energizer	Manufacturer	Ohio
Energy Control Systems, Inc.	Manufacturer	Pennsylvania
Enersys	Supplier	West Virginia
Enhanced Sintered Products, Inc.	Manufacturer	Pennsylvania
Eramet	Manufacturer	Ohio
Erie Batteries Alternators	Supplier	Pennsylvania
Eriez	Corporate Office	Pennsylvania
Evoqua Water Technologies	Manufacturer	Pennsylvania
Exide Technologies, Inc.	Manufacturer	Pennsylvania
FCX Systems	Manufacturer	West Virginia
Felman Production Inc.	Manufacturer	West Virginia
Ferroglobe	Manufacturer	Ohio
Fisher Scientific Company	Supplier	Pennsylvania
Fry Technology USA	Manufacturer	Pennsylvania
General Electric	Manufacturer	West Virginia
General Extrusions	Manufacturer	Ohio
GKN Sinter Metals	Manufacturer	Ohio
GKN Sinter Metals	Manufacturer	Pennsylvania
Global Tungsten & Powders	Manufacturer	Pennsylvania
GNB Technologies	Supplier	Pennsylvania
Graftech Usa	Manufacturer	Pennsylvania
Graybar Electric Co	Manufacturer	Ohio
Groundwater Resources	Business Services	Pennsylvania
HalenHardy	Supplier	Pennsylvania
Henwil Custom Chemicals	Manufacturer	Pennsylvania
Hi-Power LLC	Manufacturer	Pennsylvania
Höganäs	Supplier	Pennsylvania
Horizon Powder Coating	Manufacturer	Pennsylvania
Howard Industries	Manufacturer	Pennsylvania
Huntington Alloys Corporation	Manufacturer	West Virginia
Hurwitz Batteries LLC	Supplier	Pennsylvania
Hyliion	Manufacturer	Pennsylvania
II-VI Incorporated	Manufacturer	Pennsylvania
Industrial Battery-Pittsburgh	Supplier	Pennsylvania
Industrial Scientific Corporation	Supplier	Pennsylvania
INMETCO	Manufacturer	Pennsylvania
Interstate All Battery Ctr	Supplier	Pennsylvania
Interstate Chemical Company, Inc.	Manufacturer	Pennsylvania
Intervala	Manufacturer	Pennsylvania

IPEG	Corporate Office	Pennsylvania
Jenny Products	Supplier	Pennsylvania
Johnson Controls, Inc.	Manufacturer	West Virginia
Johnstone Supply	Supplier	West Virginia
KCF Technologies	Business Services	Pennsylvania
Kennametal	Manufacturer	Pennsylvania
Keystone Powdered Metal Co	Manufacturer	Pennsylvania
Kiraly Tool and Die	Manufacturer	Ohio
Kirila Fire Training Facilities, INC.	Manufacturer	Ohio
Koehler-Bright Star Inc	Manufacturer	Pennsylvania
Kraton Polymers Llc	Manufacturer	Ohio
Kurt J. Lesker Company	Supplier	Pennsylvania
Kurt J. Lesker Company	Supplier	Pennsylvania
Langeloth Metallurgical Co	Manufacturer	Pennsylvania
Li-Cycle	Manufacturer	Ohio
Liberty Pressed Metals	Manufacturer	Pennsylvania
Liquid Precision Inc	Manufacturer	Pennsylvania
Lombardi, Lloyd K., & Associates	Supplier	Pennsylvania
Lordstown Motors	Manufacturer	Ohio
Lycoming Engines	Manufacturer	Pennsylvania
Magnum Magnetics Corporation	Manufacturer	Ohio
McJunkin Red Man Corp.	Supplier	West Virginia
Mersen	Manufacturer	Pennsylvania
MetCon	Manufacturer	Pennsylvania
Mining Resistors Intl	Supplier	West Virginia
Mitsubishi Electric Power Products Inc	Business Services	Pennsylvania
Mondo Polymer Technologies	Corporate Office	Ohio
Mountain State Software Solutions	Business Services	West Virginia
Neo Solutions, Inc.	Manufacturer	Pennsylvania
New Castle Battery Manufacturing Co Inc.	Manufacturer	Pennsylvania
North American Battery Systems	Manufacturer	West Virginia
Nova Chemicals Corp.	Manufacturer	Pennsylvania
Novelis	Supplier	Ohio
Parthian Battery Solutions	Manufacturer	West Virginia
Pellbro	Manufacturer	Ohio
Penn Separator Corp.	Manufacturer	Pennsylvania
Pennsylvania Powdered Metals	Manufacturer	Pennsylvania
pHase2 microtechnologies	Corporate Office	Pennsylvania
Phillips Global	Supplier	West Virginia

Phoenix Sintered Metals, LLC	Manufacturer	Pennsylvania
Plaztuff USA	Manufacturer	Pennsylvania
Polymer Molding, Inc	Manufacturer	Pennsylvania
Powercast Corporation	Corporate Office	Pennsylvania
Powerex Inc	Supplier	Pennsylvania
PPG Industries Inc	Manufacturer	Ohio
ProChemTech International	Supplier	Pennsylvania
Production Efficiency Corp	Supplier	West Virginia
Proform Powdered Metals Inc	Manufacturer	Pennsylvania
QorTek Inc.	Manufacturer	Pennsylvania
Rebco Inc	Corporate Office	Pennsylvania
Ridgway Powdered Metals Inc	Supplier	Pennsylvania
Ritchey Metals Co., Inc.	Manufacturer	Pennsylvania
RM Battery Doctors, LLC	Manufacturer	Pennsylvania
Rochester Alloy Casting Co., Inc.	Manufacturer	Pennsylvania
Sam's Club Tire & Battery Ctr	Supplier	Pennsylvania
Sandone Tire Car Care Ctr	Supplier	Pennsylvania
Seneca Pumped Storage Generating Station	Deployment	Pennsylvania
Separation Design Group	Research and Development	Pennsylvania
Service Pump & Supply	Manufacturer	West Virginia
SGL Carbon, LLC	Manufacturer	Pennsylvania
Shape Shifter Powder Coating & Custom Metal	Manufacturer	West Virginia
Sidehill Copper Works, Inc.	Manufacturer	Pennsylvania
Silberline Manufacturing Co	Manufacturer	Pennsylvania
SMC Electrical Products	Business Services	West Virginia
SMS group	Manufacturer	Pennsylvania
Sonneborn, LLC	Manufacturer	Pennsylvania
Sparkz	Manufacturer	West Virginia
St. Mary's Pressed Metals	Manufacturer	Pennsylvania
Strategic Polymer Sciences	Research and Development	Pennsylvania
Sunpower, Inc	Manufacturer	Ohio
Surftech Inc	Manufacturer	Ohio
Symmco Inc	Business Services	Pennsylvania
T.F. Campbell Company, Inc.	Supplier	Pennsylvania
The Chemours Company	Manufacturer	West Virginia
The Penn State Research Foundation	Research and Development	Pennsylvania
TM Filtration	Manufacturer	Pennsylvania
Toyota	Manufacturer	West Virginia
TransducerWorks	Manufacturer	Pennsylvania

Transportation Research Center Inc.	Research and Development	Ohio
Tri-State Fabricators	Manufacturer	Ohio
TSP Inc	Manufacturer	Ohio
U.S. Metal Powders, Inc.	Supplier	Pennsylvania
UCAR Carbon Co.	Manufacturer	West Virginia
Ultium Cells LLC	Manufacturer	Ohio
UniFirst Corp.	Manufacturer	Pennsylvania
United States ThermoAmp Inc.	Manufacturer	Pennsylvania
Valspar	Manufacturer	Pennsylvania
Versum Materials	Manufacturer	Pennsylvania
Vertellus	Manufacturer	Pennsylvania
Vocollect, Inc	Business Services	Pennsylvania
W W Enterprises Inc.	Supplier	Pennsylvania
Wabtec Corporation	Manufacturer	Pennsylvania
WATT Fuel Cell Corp.	Manufacturer	Pennsylvania
Weastec, Inc	Supplier	Ohio
West Virginia Univ. Research Corporation	Research and Development	West Virginia
Westinghouse Electric Company	Corporate Office	Pennsylvania
Wheeling Coatings	Manufacturer	West Virginia
X2y Attenuators	Supplier	Pennsylvania
Zarbana Aluminum	Supplier	Ohio
Zimmer Surgical	Manufacturer	Ohio
Zimmerman Electrical Equipment, Inc.	Business Services	West Virginia

Source: Study Team

Appendix D: Role of Social Justice, Decarbonization, and National Security in Energy Storage Strategies for Northern Appalachia (Full Discussion)

Procurements Mandates

Procurement mandates are tools for state governments to require distribution utilities to purchase a certain amount of energy storage, usually measured in Megawatts.[198] As opposed to a subsidy for energy storage research and development, which could be funded by income taxes, a mandate requires utilities to fund the purchases. In a monopolistic economic environment like that held by electricity distribution companies, this could pose **social justice** concerns, since they can easily pass costs on to ratepayers. According to a report by the American Council for an Energy-Efficient Economy, low-income households spend 8.1% of their income on energy compared to 2.3% for other households.[199] Additionally, the median energy burden for black households is 43% higher than that for non-Hispanic white households. This suggests that the cost of energy storage mandates would fall more heavily on low-income and minority households than other households.

From a **decarbonization** standpoint, the picture is rosier. Procurement mandates would make low-carbon energy sources more viable. This is because energy storage increases use of the cheapest low-carbon energy sources.[200] States that require purchase of energy storage capacity will thus make it easier for wind, solar, and other low-carbon intermittent energy sources to replace higher-carbon uses of energy.

Energy procurement mandates could have mixed impacts on **national security**. Some have argued that reducing the use of fossil fuels will create more energy independence.[201] Energy storage could also become a new target for agents working to destabilize the U.S. economy. Transmission companies working to ramp up energy storage quickly could invest in centralized storage, which would concentrate energy storage in certain areas. This could be mitigated by mandates for decentralized energy storage.

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[198] Burwen, Jason, “Energy Storage Goals, Targets, Mandates: What’s the Difference?,” The ESA Blog, Energystorage.org, April 24, 2020, Available Online: https://energystorage.org/energy-storage-goals-targets-and-mandates-whats-the-difference/

[199] Drehobl, A., L. Ross, and R. Ayala. 2020. How High are Household Energy Burdens? Washington, DC: American Council for an Energy-Efficient Economy.

[200] De Sisternes, Fernando J., Jesse D. Jenkins, and Audun Botterud. "The value of energy storage in decarbonizing the electricity sector." Applied Energy 175 (2016): 368-379.

[201] Seip, Norman R., “Renewable Energy as a Key National Security Interest,” Global Institute of Sustainability and Innovation, Julie Ann Wrigley Global Futures Laboratory, Arizona State University, May 12, 2014, Available Online: https://sustainability-innovation.asu.edu/news/archive/renewable-energy-as-a-key-national-security-interest/

Financial Incentives, Subsidies, and Tax Credits

Subsidies for energy storage have **social justice** considerations on both sides of the ledger. Since much energy storage is not viable on its own for large-scale deployment, subsidies will make these projects likely. The state can accompany subsidies with qualifications for hiring practices or deployment that can further social justice goals. For instance, late last year the federal government launched the Energy Storage for Social Equity Initiative (ES4SE)—to assist as many as 15 underserved and frontline communities to leverage energy storage as a means of increasing resilience and maximizing energy flexibility.[202]

Subsidies and tax credits can also encourage **decarbonization**. By tying the rate and availability of incentives for energy storage to reductions in greenhouse gas emissions, policymakers can make financial incentives a tool for effective decarbonization.[203]

State tax incentive policy could supplement federal policy around battery storage. The federal government currently only awards tax credits for battery storage when it is paired with solar projects.[204] Creating a tax credit for standalone battery storage could reduce reliance on foreign supply chains and manufacturing and meet a growing military need for reliable battery technology, both bolstering **national security** prospects.

Utility Ownership of Energy Storage Assets

A May 2021 review of the literature on energy storage as an equity asset tackles the **social justice** considerations for utility ownership of energy storage assets.[205] In particular, it stresses the importance of distributed ownership, community ownership, and co-ownership of energy storage assets. Utility ownership of energy storage assets has the potential to undermine social justice considerations of recognition justice and procedural justice, leading to a desire for more distributed ownership structures for energy storage assets.

Utility ownership of energy storage assets seems like a natural approach to **decarbonizing** utility-level energy systems. Decarbonization has also happened in decentralized energy storage settings and some researchers argue that well-functioning power markets and efficient tariffs will lead to growth in distributed energy storage.[206]

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[202] "Energy Storage for Social Equity Initiative," Office of Electricity, US Department of Energy, November 3, 2021, Available Online: https://www.energy.gov/oe/articles/energy-storage-social-equity-initiative
[203] Bilich, Andy, Elisheba Spiller, and James Fine. "Proactively planning and operating energy storage for decarbonization: Recommendations for policymakers." Energy Policy 132 (2019): 876-880.
[204] Jackson, Christopher T. "Revamping Battery Storage Policies to Bolster US National Security." (2021).
[205] Tarekegne, Bethel, Rebecca O'Neil, and Jeremy Twitchell. "Energy Storage as an Equity Asset." Current Sustainable/Renewable Energy Reports (2021): 1-7.
[206] Shen, Bo, Fredrich Kahrl, and Andrew J. Satchwell. "Facilitating Power Grid Decarbonization with Distributed Energy Resources: Lessons from the United States." Annual Review of Environment and Resources 46 (2021): 349-375.

According to the DOE, a limitation of renewable energy resources is that, unlike oil, they cannot be stored at scale in order to be deployed rapidly.[207] Utility ownership of energy storage assets could remedy this problem, thus being an asset for **national security**. On the other hand, centralized storage could be an easier target for cyber and terror attacks than a more decentralized system.

Inclusion of Energy Storage in Utility Integrated Resource Plans

Integrated resource planning is fundamentally an approach that advances **social justice** concerns. A key characteristic of the integrated resource plan is public participation, which brings different perspectives to the decision-making process and thus furthers procedural justice as a practice.[208] Including energy storage in utility integrated resource plans will help bring stakeholders of all types to the decision-making process around energy storage.

Another key characteristic of integrated resource planning is consideration of environmental factors in conjunction with direct economic costs.[209] Since energy storage deployment will be necessary for adoption of renewable energy sources such as solar and wind, factoring energy storage into integrated resource planning will advance **decarbonization** goals as well.

National security considerations may be a little more murky here. In an age of manufactured democratic participation, the nature of participation in this process may introduce some participation from people who do not have public interests at heart, which could undermine national security. On the other hand, a public planning process could make it easier for security professionals to coordinate with utilities in promoting energy storage deployment and technology that furthers national security goals.

Changes to Net Energy Metering Policies

Pairing storage technologies with net metering may cause some **social justice** concerns as a core problem with combining this technology with this policy is how to make the combination fair for all parties involved.[210] In particular, some believe a net energy metering policy should be adjusted so storage users don't buy energy when it is cheap and sell it when it is expensive under differential time of use prices.

Creating net energy metering policies that encourage adoption of energy storage technology could further encourage **decarbonization** as well. Having home energy storage can improve reliability and lower costs of energy for consumers, thus encouraging adoption of renewable energy technology and reducing reliance on carbon-emitting energy sources.

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[207] DOE, US. "Transforming the Nation's Electricity System: The Second Installment of the QER." Technical Report (2017).

[208] Hirst, Eric, and Charles Goldman. "Creating the future: integrated resource planning for electric utilities." *Annual review of energy and the environment* 16, no. 1 (1991): 91-121.

[209] Ibid.

[210] Mow, Benjamin, "The Solar Energy Trifecta: Solar + Storage + Net Metering," State, Local, and Tribal Governments Blog, NREL, February 12, 2018.

Creating a regulatory environment that encourages adoption of both technologies could also increase usage of home and business energy storage. This could decentralize regional energy storage and make it harder for those looking to threaten **national security** to destabilize the electricity system.

Changes to Renewable Portfolio Standard Programs

Renewable portfolio standards increase prices by requiring adoption of power generation technologies that are more expensive.[211] At the same time, they create benefits in the form of improved health from reduction in air pollution and reduction in climate change damages. Increased prices are likely to hurt low-income consumers more than middle- and high-income consumers, but some low-income ratepayers may also benefit from cleaner air. Climate change benefits would likely be spread throughout the world, not having as much of an impact locally. The relative magnitude of these impacts is a key consideration when assessing the **social justice** impact of renewable portfolio standards.

By definition, renewable portfolio standards promote **decarbonization**. Requirements to reduce use of nonrenewables will reduce the amount of carbon emitted into the atmosphere.

Renewable portfolio standards could promote **national security** by reducing reliance on nonrenewables secured in other countries.[212] Standards could also cause some problems for national security by making power more expensive. Policymakers would likely suspend these standards in times of need, but they could cause some problems if battery technology is not to the point it needs to be in a situation when national security forces need to use battery technology.

Multiple Use Applications

In 2018, the state of California adopted rules for energy storage to be used in multiple ways.[213] Since energy regulation is at its heart about allowing a market to exist without creating an exploitative environment, making sure energy storage is not a backdoor to exploitation is a key **social justice** concern.

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[211] Wiser, Ryan, Trieu Mai, Dev Millstein, Galen Barbose, Lori Bird, Jenny Heeter, David Keyser, Venkat Krishnan, and Jordan Macknick. "Assessing the costs and benefits of US renewable portfolio standards." Environmental Research Letters 12, no. 9 (2017): 094023.

[212] Endrud, Nathan E. "State renewable portfolio standards: Their continued validity and relevance in light of the dormant commerce clause, the supremacy clause, and possible federal legislation." Harv. J. on Legis. 45 (2008): 259.

[213] Gergen, Michael, et al, "California Adopts Rules for Evaluating Multiple-Use Energy Storage Resources," Latham's Clean Energy Law Report, Latham & Watkins LLP, January 24, 2018, Available Online: https://www.cleanenergylawreport.com/energy-storage/california-adopts-rules-for-evaluating-multiple-use-energy-storage-resources/

Allowing for multiple use can be key to supporting **decarbonization**. Energy storage has the potential to create value at different points in the electrical grid.[214] This means there will be more opportunities for the grid to use stored energy rather than create new energy, thus lessening reliance on carbon-intensive power sources.

Allowing for varied use of energy storage has clear **national security** implications. If energy storage can be deployed at different points in the grid, that will improve grid-scale resilience and reliability, making the grid less vulnerable to actors that may destabilize it.

Cost-Benefit Analysis (Valuation)

Cost-benefit analysis is a valuable tool for understanding who benefits from and who is hurt by a policy. By conducting cost-benefit analysis of regulatory decisions, regulators can understand how a given policy impacts different stakeholders, distributional analysis that is key for understanding the **social justice** implications of a policy change.

Cost-benefit analysis can also be valuable for understanding how **decarbonization** interacts with other policy impacts. For instance, a recent cost-benefit analysis of renewable portfolio standards found the benefits of these policies far outweighed the costs incurred by ratepayers for higher energy costs.[215]

Cost-benefit analysis, in particular when combined with risk analysis, can also be valuable for analyzing the **national security** implications of policy change. By assigning probabilistic weights to outcomes and assessing the costs associated with different scenarios, policymakers can understand which approaches will lead to higher national security risks compared to alternative policies.

Distribution System Modeling

Distribution resource plans such as those required by the state of California can be used to promote an equitable distribution of energy storage, a concern from a **social justice** standpoint. Since the California code requires utilities to “identify optimal locations for the deployment of distributed resources.” Optimality can be defined by the Public Utilities Commission to include an equity criterion.

Decarbonization can also be included as a criterion for identifying optimal locations for energy storage resources. Utilities can identify locations that would shift energy usage more drastically away from carbon-intensive power sources and prioritize those over areas of low current carbon intensity.

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[214] Balducci, Patrick J., M. Jan E. Alam, Trevor D. Hardy, and Di Wu. "Assigning value to energy storage systems at multiple points in an electrical grid." Energy & Environmental Science 11, no. 8 (2018): 1926-1944.
[215] Wiser, "Assessing the costs and benefits of US renewable portfolio standards."

Just like equity and carbon, **national security** can be rolled into distribution system modeling. Utilities can follow guidance from security experts to improve grid reliability and resilience and to make it able to withstand unexpected shocks.

Changes to Interconnection Standards

Interconnection standards that incorporate energy storage could be valuable from a **social justice** perspective. Areas that experience intermittent blackouts and energy system reliability issues often are areas that have more low-income residents. By building energy storage into interconnection standards and introducing an equity dimension, these residents could end up with more reliable power than they would otherwise.

Building energy storage into interconnection standards can also help facilitate **decarbonization**. Since energy storage is a useful tool for encouraging the use of energy sources that do not emit carbon, factoring them into interconnection standards in a way that facilitates reduction in carbon will improve prospects for reducing carbon emissions in the electrical grid.

Interconnection standards are also likely to have **national security** implications. Energy storage can be a tool for promoting grid reliability and resilience, which is key for promoting national security interests, both for civilians and the military.

ZEV mandate (sales requirements)

ZEV mandates work a lot like renewable portfolio standards or other requirements for companies to move away from fossil fuels. Because of this, they pose some concerns from a **social justice** perspective: in particular how to keep prices for goods affordable for people with less resources. A ZEV mandate may pose less problems since vehicles are durable goods and can be purchased used, but reducing the supply of cars and only allowing for more costly energy sources for fuel will increase costs for low-income people.

ZEV mandates will promote **decarbonization** by encouraging people to move away from the use of gasoline. This will only work, however, if electricity is generated using low- or zero-carbon technology. If electricity is still generated using coal or natural gas, ZEV mandates could be just as or even more carbon-intensive as the status quo.

From a **national security** perspective, ZEV mandates could be useful by reducing reliance on petroleum reserves in other countries. They also could be useful for improving technology for batteries for vehicles, which could then be used in military vehicles in the future. They also could endanger national security, though, if grid reliability then starts to threaten the ability of vehicles to get access to energy in the short-term in a time of crisis.

Fuel Economy Standards

Standards for miles per gallon look similar to ZEV mandates from an economic perspective, in direction if not in magnitude. If fuel economy standards have any impact on the type of cars that are manufactured and sold, they will become more expensive for consumers, which will hit low-income consumers harder, a concern from a **social justice** perspective.

Fuel economy standards will allow consumers to go further on less gas, which will lead to less use of fossil fuels and thus facilitate **decarbonization.**

Fuel economy standards may facilitate some development of higher fuel economy vehicles, which could be useful from a **national security** perspective. It also could reduce demand for gasoline, which would lessen reliance on foreign oil.

Weight Exemptions for Heavy-Duty ZEVs

Allowing heavy-duty ZEVs to be exempted from weight restrictions could encourage more wear and tear on roads, which could then deteriorate infrastructure faster than it would otherwise. This could have **social justice** impacts as it would end up hurting users of roads by effectively subsidizing the activities of heavy-duty vehicle owners and users.

While roads may deteriorate, encouraging heavy-duty vehicle users to opt for zero-emission vehicles would support **decarbonization** goals. More zero-emission vehicles on the road and less emitting vehicles will reduce carbon emissions in industries such as trucking that use a lot of heavy-duty vehicles.

Deteriorating roads could have some **national security** implications, though. Roads that are deteriorated will be harder to move equipment and people on, thus making them less useful in a time when resources would need to be mobilized across the country.

Vehicle purchase direct incentives

Direct incentives could benefit upper-income people at the expense of lower-income people if they are only targeted at marginally subsidizing expensive technology. Direct incentives for purchase of cars that utilize energy storage technology could have **social justice** implications if only upper-income people end up using them.

Vehicle purchase direct incentives geared toward zero emission vehicles that utilize energy storage technology would likely promote **decarbonization**. The exception would be if the energy stored were generated from carbon-intensive sources.

Direct incentives would likely improve **national security** prospects on the margins. It would do this by encouraging the development of vehicles that do not rely on diesel fuel that can be used in military deployments. These technologies would also be useful in reducing reliance on foreign oil sources.

Develop hardware standards and building regulations for vehicle charging equipment

Making sure that vehicle charging equipment meets certain hardware standards and building regulations could be a way to protect public safety, particularly for disadvantaged groups that could be hurt by weak standards. Thus, **social justice** concerns about inequities could be curbed by smart standards and regulations.

Onerous standards and regulations, though, could undermine **decarbonization** efforts. Standards and regulations have played a key role, for instance, in the slowdown of the United States nuclear energy industry. If standards and regulations are too difficult to navigate, it will be harder for vehicle charging equipment to be installed and it will slow efforts to use electric vehicles to encourage decarbonization.

Hardware standards and building regulations could be important for encouraging development of equipment that is safe, thus less likely to be tampered with and posing less **national security** risks.

Direct incentives for charging equipment and supporting infrastructure, including to utilities

Incentives for charging equipment are likely to benefit upper-income people at first, causing some **social justice** concerns in the short-run since these incentives will mostly benefit upper-income people.

These incentives will likely support **decarbonization** by making it easier for people to use electric vehicles and thus reduce the burning of petroleum in cars. This will only cause a net decrease in carbon emissions, though, if the power sources used to charge cars are generated from sources that emit less carbon than petroleum does.

Incentives for charging equipment and supporting infrastructure can also bolster **national security** by creating a system for powering vehicles that is less dependent on petroleum than the current system, thus fostering US energy independence and creating new ways to power military vehicles.