Southeast Clean Energy Opportunities Roadmap

North Carolina Roadmap: Lithium-Ion Battery Manufacturing Industry

A project funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, State Energy Program

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Executive Summary

Since the implementation of North Carolina's 2007 Renewable Energy and Energy Efficiency Portfolio Standard (REPS), the clean energy industry in the state has boomed. Approximately $6.3 billion has been invested in the clean energy industry between 2007 and 2015, resulting in a total economic impact of $12 billion for the state. North Carolina is now home to 989 firms that employ 26,154 full time equivalent (FTE) jobs and generate $6.96 billion in revenue.

Strong energy policies, including the state's REPS and the Renewable Energy Investment Tax Credit (REITC), are largely credited for the vast growth of North Carolina's top renewable energy sector, solar. North Carolina is currently ranked third in the country for cumulative installed solar photovoltaic (PV) capacity and in 2015, the state was second in the country for new solar installations. This large investment in solar makes North Carolina a desirable market for energy storage deployment given the complementary nature of the two technologies. The NC Sustainable Energy Association's (NCSEA) annual Clean Energy Industry Census found that in 2015 there were already 486 FTE employees in the energy storage industry, making it the largest contributor to clean energy manufacturing jobs in the state. In addition, it was the sector with the third highest revenue of all clean energy manufacturing.

The majority of the companies participating in North Carolina's energy storage manufacturing industry are involved in the production of components for lithium-ion batteries (LIBs). Because of this, the North Carolina team focused their efforts on the LIB sector for the U.S. Department of Energy Clean Energy Opportunities Roadmap. North Carolina is an attractive place to locate and grow companies involved in LIB manufacturing because of its strong clean energy manufacturing sectors, existing ties to the regional economy, business friendly climate, and world-class higher education system with growing research and development opportunities. The different sections of the North Carolina Roadmap: Lithium-Ion Battery Manufacturing Industry are described below.

The **The Starting Point: Energy Storage Overview** section provides background on how energy storage technologies function and their general benefits, with a particular focus on LIBs. The overview also highlights how an investment in LIBs can be a tremendous asset for grid energy storage and electric vehicles applications, because of their high energy and power densities, fast discharging, and useful life of 10-15 years.

The **Road Signs: Market Conditions** section describes the energy storage market and opportunities for LIB manufacturing on a global, national, and state level. LIB manufacturing success is attributed to the increased use of renewables, demand growth from consumer electronics and electric vehicles applications, and favorable polices and regulations. Technological improvements and cost reductions have also accelerated battery adoption by the electricity sector, and as a result, the global market for LIBs is projected to reach $24.2 billion by 2018.

The section entitled **The Route: Opportunities for Making LIBs in NC** examines opportunities for large scale LIB production in North Carolina. The state boasts a diverse energy workforce, world-class research institutions, access to capital, headquarters for one of the nation's largest investor owned utilities, Duke Energy, and a thriving energy economy. All of these factors make the state an attractive location for LIB manufacturing. Despite these successes, North Carolina and the U.S. as a whole, have an immature LIB supply chain. New entrants to the industry will face challenges in establishing cost-competitive, high-volume production against global leaders. However, North Carolina may overcome these shortcomings, because it is home to key assets for a robust LIB supply chain, such as natural deposits of lithium and several established firms.

The last two sections, **Potential Roadblocks: Barriers to Deployment and Manufacturing** and **Shortcuts: Addressing Barriers through Strategic Opportunities** address how North Carolina can work to enhance and deploy manufacturing opportunities for battery storage in the state. Batteries face a variety of barriers in both implementation and production, ranging from regulatory limitations to a lack of well-defined business models. Development of industry standards, application of pilot projects, and determination of a clear value for LIBs in grid-storage applications will help overcome these hurdles. Working groups, such as the NCSEA's Storage Working Group, have been formed to analyze how a regulatory structure would govern storage deployment in North Carolina and expand markets for storage technologies. Additional strategies for energy storage deployment include, identifying key commercialization partnerships, analyzing workforce development needs, and creating a LIB supply chain map.

Project Overview

The Southeast Clean Energy Opportunities Roadmap is a project funded through the U.S. Department of Energy's (DOE's) State Energy Program. The Roadmap complements a DOE effort to enhance U.S. clean energy manufacturing development.[1] The DOE clean energy roadmap project was intended to bring together key stakeholders in clean energy sectors and related organizations to identify strategic opportunities for increasing clean energy employment. Roadmaps can provide clear economic development strategies and make a convincing case for their implementation by explaining the expected benefits of increased investment in clean energy in states and/or regions. The roadmap process included:

- Baselining existing assets, including clean energy production facilities, clean energy services providers, supply chains, research and development capacity, industrial consortia, infrastructure, and workforce development resources;
- Examining clean energy market opportunities to assess their alignment with existing, as opposed to aspirational, regional manufacturing and other resources; and,
- Identifying key areas of regional competitive advantage.

The DOE selected the Southeast region, consisting of Virginia, North Carolina, South Carolina, and Georgia, as one of three regions to participate in the 2014 roadmap grant. The project team included fourteen partners from across all four states. Four state roadmaps were produced that focused on specific clean energy industries, and a regional roadmap outlined the assets and competitive advantages found in the region collectively. The team also implemented a Clean Energy Census across the four-state region. The Census, available at www.cleanenergyindustry.org, surveyed clean energy businesses across 10 clean energy sectors to assess jobs and revenue information. The project team held community forums, state-level dialogues for industry feedback, as well as in-person interviews to assess stakeholder understanding of clean energy business markets, opportunities, assets, and barriers.

North Carolina

North Carolina is a growing clean energy industry hub in the Southeast. In 2007, North Carolina adopted a Renewable Energy and Energy Efficiency Portfolio Standard (REPS) that aimed to promote the development of clean energy resources by requiring electric utilities to meet a portion of their electricity sales with renewable energy and energy efficiency. The REPS, along with the state's Renewable Energy Investment Tax Credit (REITC) established North Carolina as a solar energy industry leader. North Carolina now ranks third in the nation for cumulative installed PV capacity, behind California and Arizona.[2]

While solar energy has been the renewable energy sector's biggest success story, North Carolina's overall clean energy industry includes a at total of 989 firms who employ 26,154 full time jobs and generate $6.96 billion in revenue.[3] The clean energy industry has generated millions of dollars of investment in some of the state's most economically depressed counties (tier 1 and tier 2 counties) and the investment has grown over time. In fact, investments in 2014 and 2015 accounted for 58% of total cumulative investment over last 9 years. For example, in 2007, the investment value was estimated to be $47.5 million, and by 2015 this value grew to $2,250.4 million.[4] The Clean Energy Roadmap grant provides a unique opportunity for North Carolina to continue its economic development through the identification and alignment of key assets and opportunities in the state.

Southeast Clean Energy Opportunities Roadmap Project Team

The Southeast Clean Energy Opportunities Roadmap project is a collaborative effort built around a diverse group of partners from different organizations and geographic areas. Each partner brings knowledge of their own state and industry relationships. The project lead for each state selected their team based on areas of expertise and knowledge of state energy assets. Many of the partners had a history of collaboration through the Southeast Clean Energy Industry Census, an annual report that measures the impact of clean energy policies and identifies where they are or are not achieving the results policymakers, economic developers, and industry envisioned. The project team remained engaged during the project through steering committee meetings, break out groups, webinars, and a regional retreat.

List of Roadmap Partners:

- NC Sustainable Energy Association
- Southern Governors' Association
- North Carolina Clean Energy Technology Center at NC State University
- Institute for Emerging Issues at NC State University
- NC Department of Environmental Quality, State Energy Program
- E4 Carolinas
- Advanced Energy
- Southface Energy Institute
- Virginia Energy Efficiency Council
- Southeastern Wind Coalition
- South Carolina Energy Office
- Virginia Division of Mines, Minerals and Energy
- South Carolina Clean Energy Business Alliance
- Georgia Environment Finance Authority

Purpose & Objective of NC Roadmap – Lithium-Ion Battery Manufacturing

The North Carolina Lithium-Ion Battery Manufacturing Roadmap is intended to help guide the industry's future economic development through a detailed understanding of the state's assets and opportunities. Recommendations from this roadmap are designed to help inform industry decision makers on what needs to be done to make North Carolina a national leader in manufacturing.

Objectives

Objective #1: Engage with key industry stakeholders through dialogues, forums, and industry leader interviews and identify industry assets, obstacles, and areas of competitive advantage.

Objective #2: Develop a comprehensive understanding of North Carolina's industry assets, including firms, manufacturing facilities, supply chain components, research and advocacy organizations, and workforce development programs and resources.

Objective #3: Develop strategic action items specific to the assets and needs of North Carolina's lithium-ion industry to increase advanced manufacturing jobs, grow the local tax base, and increase exports.

Objective #4: Provide industry leaders, economic developers, universities, policy-makers, and other key stakeholders with a document that can be used to advance the lithium-ion battery manufacturing industry in North Carolina.

NC Roadmap Team

The North Carolina Roadmap team was comprised of four organizations that collaborated on the process and production of the final document. NC Sustainable Energy Association (NCSEA) is a nonprofit organization dedicated to driving public policy and market development that creates clean energy jobs, economic opportunities, and affordable energy to benefit all of North Carolina. NCSEA brings a strong reputation of collaboration with business, policy-makers, and consumers to the Roadmap project. As the author of the Southeast Clean Energy Industry Census, NCSEA has provided the project with expertise and intricate knowledge of the clean energy economy in the four state region. The Census served as a primary quantitative data input, as well as a starting point for understanding the clean energy industries.

The NC Department of Environmental Quality (NCDEQ), State Energy Program, served as the administrative project coordinator and the primary contact with the DOE. The State Energy Program has a long history of involvement in the clean energy arena- holding conferences, funding clean energy projects, and doing outreach and education.
The North Carolina Clean Energy Technology Center (NCCETC) is a University of North Carolina (UNC)-chartered Public Service Center within North Carolina State University. Its mission is to advance a sustainable energy economy by educating, demonstrating, and providing support for clean energy technologies, practices, and policies. The NCCETC brings an extensive knowledge and expertise on North Carolina's clean energy economy to the roadmap project.

The Southern Governors' Association (SGA) specializes in designing and drafting economic development guidelines for a variety of industries. The SGA has extensive experience with community engagement through a tested method that includes state dialogues and community forums. These best practices were used in the roadmapping process to develop state and industry specific dialogues that provided qualitative data for the project.

Focus on Lithium-Ion Battery Manufacturing

Given the strong presence of North Carolina's LIB industry, recent growth in the sector, and the importance of the industry to the overall clean energy economy, the roadmap team selected the LIB manufacturing industry as the focus of the North Carolina roadmap. The decision to focus on one technology in the larger energy storage industry allowed the roadmap team to examine a specific industry and identify strategies to grow that industry. Given available resources and time, a thorough and tailored investigation of one industry, rather than a surface-level overview of multiple industries, allowed the team to maximize the efficacy of the roadmap project.

Clean energy manufacturing in North Carolina has benefited from the growth of the energy storage sector. According to the Clean Energy Industry Census, the energy storage industry's 486 FTE jobs is the largest contributor to clean energy manufacturing jobs in the state, outpacing the next largest manufacturing sector, energy efficiency, by nearly double.[5] Energy storage manufacturing generates the third highest revenue out of all clean energy manufacturing industries, trailing only solar and energy efficiency. The energy storage industry includes a wide variety of technologies, such as batteries, flywheels, compressed air, pumped-hydro, and thermal. A majority of companies participating in energy storage manufacturing make components for LIBs. These companies, along with firms that did not participate in the Census, make up a robust supply chain, and the strong jobs and revenues indicate a strong manufacturing sector.[6]

The LIB industry in North Carolina received a huge boost in 2014, when the grid-scale battery manufacturer, Alevo, announced it would be opening its U.S. manufacturing headquarters in Concord, NC. Alevo purchased its 3.5 million square foot manufacturing facility for $68.5 million and expects to generate 500 new jobs in the first 12 months of operation, a number that could rise to 6,000 if the plant eventually produces additional manufacturing components.[7] The size and expected output of the facility highlights the growing LIB industry in North Carolina and the market size in the region. Alevo's grid battery storage system manufacturing facility joins Celguard, FMC Lithium, and Rockwood Lithium, as the newest, and one of the largest, pieces of the state's LIB supply chain. Located in the Charlotte metropolitan region, this grouping of battery supply chain companies has the potential to draw in additional companies that wish to participate in the growing cluster of related battery industries.

Market applications for lithium-ion (and other batteries) include: support to utility grid operations by managing demand peaks, shifting load, and integrating intermittent generators. Additionally, LIBs and other batteries can be marketed to consumers for their ability to supply power during outages, manage customer peak charges, and improve operation of intermittent customer-owned generation. Another major market for advance batteries is the transportation market, which includes cars, buses, and other heavy vehicle applications. With a clear vision of North Carolina's assets, obstacles, and opportunities, the LIB sector will thrive and become a national leader.

1 Starting Point: Energy Storage Overview

Electricity is a unique commodity that must be used at the same time and in the same amount as it is generated. Energy storage is a highly valuable component of the electricity grid that can both provide power when it is needed and perform a variety of ancillary services.[8] With increased deployment throughout the world, energy storage is quickly becoming an essential component in developing resilient and reliable energy systems. Renewed interest in energy storage deployment has been encouraged by advances in storage technologies, volatile fossil fuel prices, business opportunities in deregulated markets, transmission and distribution challenges, and the increased penetration of variable renewable resources.[9] While grid-scale energy storage has traditionally been achieved by using pumped-hydro systems, there are a variety of technologies such as compressed air energy storage, flywheels, and batteries capable of performing the task. In recent years, LIBs have become the focus of new energy storage development because of favorable technological properties that allow for energy management, backup power, load leveling, frequency regulation, voltage support, and grid stabilization. Currently, there are more than 180 megawatts (MW) of grid-connected LIB systems installed or under construction globally, and this roadmap provides an in-depth look at their potential in North Carolina's clean energy economy as both a growing manufacturing sector and as a new resource for creating an advanced electricity grid.[10, 11, 12]

Energy Storage Technology Overview

Energy storage systems can provide vital support to the aging electricity grid, by not only storing energy for later use, but also ensuring energy and infrastructure resiliency, while keeping costs low for utilities and customers.[13] While pumped-hydro constitutes the vast majority of energy storage worldwide, accounting for roughly 99% of all installed capacity, there are a variety of technologies suitable for different applications. The U.S. DOE/Sandia Global Energy Storage Database includes twenty five different technologies, twenty two of which are battery technologies.[14, 15]

LIB cells are composed of alternating sheets of an anode (most commonly graphite), a separator, and a cathode (most commonly lithium cobalt oxide). These sheets are immersed in an electrolyte solution – typically a solution of lithium salts and an organic solvent – such that ions flow between the cathode and anode. This combination of cathode, anode, separator, and electrolyte can be placed into a variety of container shapes, such as a cylinder or a prism.
Source: CEMAC (2015) , IRENA (2013), Cunningham (2015)

Battery Technology

Batteries work to store and discharge energy through an electrochemical reaction involving the movement of ions to and from charged electrodes. The size of a battery can be measured both in terms of megawatts (MW) and megawatt hours (MWh). A battery's MW capacity refers to the amount of power it can generate at any given instant in time; while its MWh refers to the number of hours it can operate at its given MW capacity. Thus, a battery system will consist of delivering a certain MW rated power capacity for a certain number of hours. For instance, a 1 MW, 4 MWh system can deliver 1 MW of power for 4 hours.[16]

Lithium-Ion Battery Technology

A lithium-ion battery is a rechargeable battery where lithium-ions move back and forth between positive and negative electrodes to charge and discharge energy. Their success is largely due to their chemical and technological properties. LIBs have a high energy density (energy in relation to volume), a high power density (rate at which energy changes), and high round trip efficiency of between 80-90% (the amount of energy that can be charged and then discharged without internal losses), enabling them to perform well in compact spaces, such as in electric vehicles. This combination allows them to effectively control frequency regulation, as well as perform other services that require rapid discharge and high power performance. Research and development, supply chain build-out, and steady technology improvements over the past 20 years have made lithium-ion batteries the leading choice for power sector applications.[17] However, battery manufacturers are working continuously to minimize the presence of volatile particles, and are making great strides to improve manufacturing methods to enhance safety. Lithium-ion batteries offer an array benefits, but also face several disadvantages.

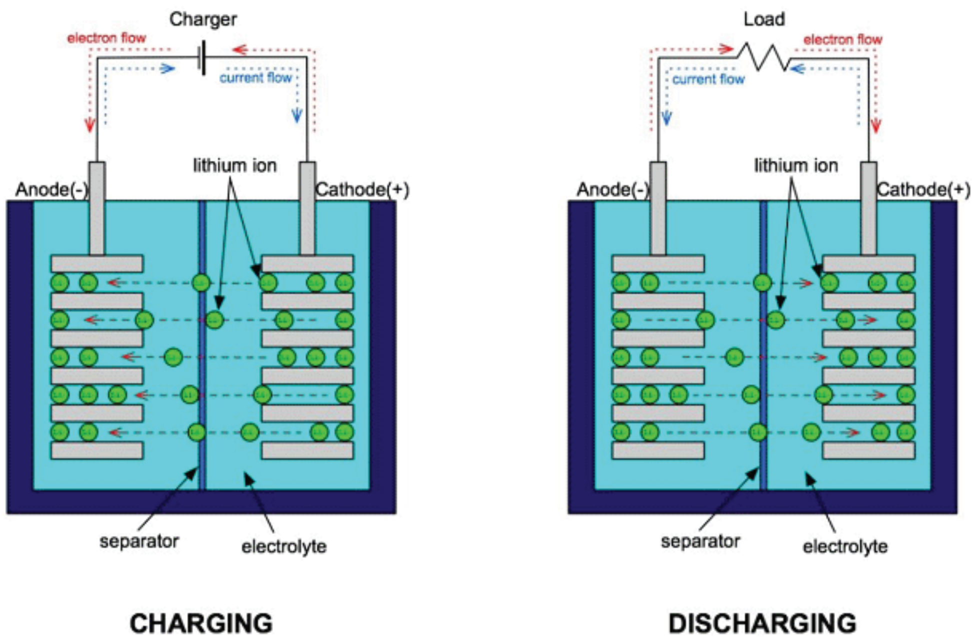

Figure 1: Lithium-Ion Battery
Source: http://theelectricenergy.com/lithium-and-lithium-ion-battery/

While they are capable of fast response times, high efficiency, and are convenient, their high price and problems with charging and discharging must be overcome before there is wide adoption.[18, 19]

Energy-Related Applications of LIBs

Electric Energy Storage

The wide array of services that batteries can provide, coupled with their ability to be deployed in a variety of locations, make them the most promising approach to grid energy storage currently available. For example, batteries can defer the need for transmission and distribution upgrades, they can store energy for use when the price of purchasing is high, and can provide ancillary services such as frequency regulation.[20, 21] Batteries allow intermittent renewable energy generation to integrate well with other components of the electricity grid, and allow end-users to reduce both energy costs and demand charges.[22, 23] More benefits specific to grid operations and end-users are given in Appendix 1.

Electric Vehicles

LIBs have become the best choice for electric vehicles (EV) because of their small size, ability to deliver a large amount of energy quickly, and long lifespan. Sales of all EVs are expected to grow over the next several years, contributing to increased LIB production for the automotive industry. However, demand for EVs will depend on several factors, such as corporate average fuel efficiency (CAFE) standards, government subsidies and deployment of EV infrastructure.[24]

2 Road Signs: Energy Storage Market Conditions

Energy storage has become a valuable contributor to the energy sector. By allowing for delayed consumption of electricity, energy storage has the potential to change the way intermittent sources operate, quickly meeting changes in electricity supplied by wind and solar generation. Renewed interest in energy storage over the past decade has been motivated primarily by declining costs of technologies, volatile fuel prices, new markets opportunities, transmission and distribution challenges on the electricity grid, and the emergence of intermittent renewable energy generation.

Global and National Energy Storage Market Outlook

Despite the large deployment of variable energy resources and decreasing costs of batteries, grid-scale energy storage is still rare. The economies of scale and competition in the marketplace that caused a decrease in the price of solar were a result of favorable policies and mandates that drove demand, and it is possible for energy storage to be similarly enabled by policy and legislative decisions, rather than technological breakthroughs leading to lower installation costs.[25]

According to Advanced Energy Economy (AEE), from 2014 to 2015, the energy storage market in the U.S. increased ten-fold, from $58 million to $734 million with this market growth expected to continue.[26] It is estimated that the deployments of utility-scale LIB energy storage in the U.S. will increase from 237 MW in 2016 to about 2.1 GW in 2021.[27, 28]

Drivers of Energy Storage Market Growth

This impressive rate of energy storage growth has been driven by several factors. First, rapidly declining costs of renewable energy, particularly solar, has led to its increased market penetration of intermittent resources that can be supported by the deployment of energy storage systems.[29] Second, energy storage has the ability to meet additional grid challenges such as frequency regulation, fast response services, and load shifting. Finally, as productions and supply of energy storage systems increases to meet the new energy storage demand, prices fall, further increasing the use in new applications in a positive feedback loop.

The Role of LIBs in the Energy Storage Market

Lithium-ion batteries have declined in price over the past several years, primarily in the laptop and consumer electronics industry.[30] Grid-scale battery technologies have also advanced, and with increased industry awareness, have become increasingly cost competitive in the market.[31] According to GTM research, investment in energy storage was strong in 2015 and expected to be even greater in 2016, with electric utilities driving this market growth, through investment in pilot programs and additional research.[32] Structured electricity markets such as Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) currently offer the most valuable opportunity for grid-connected batteries. PJM Interconnection, an RTO that coordinates the movement of wholesale electricity, has seen dramatic growth in battery deployment since it restructured its wholesale electricity market to meet a Federal Energy Regulatory Commission (FERC) mandate that markets pay fast-responding frequency regulation resources, such as batteries, flywheels, and demand response, based on their performance following a dispatch signal. PJM is the territory with the highest deployment of energy storage in the U.S., combing with California, the area with the second highest deployment, for 92% of the entire market share.[33]

Regulatory Considerations in the United States

While the policy and regulatory environment for energy storage is still taking shape as markets are adapting to new technologies, installations have increased and storage is providing an array of benefits. Growth in U.S. battery storage deployment has been driven by favorable regulatory policies, state-level storage mandates, renewable support programs, and the country's 2009 federal stimulus package, the American Recovery and Reinvestment Act (ARRA). The ARRA funds provided roughly $100 million for electricity sector battery storage projects, and the private sector provided an additional $122 million for battery storage implementation. This stimulus package also provided $2.4 billion for the development of EVs, with a portion going to increasing manufacturing capability.[34]

The higher barrier to widespread energy storage adoption is determining appropriate compensation for the variety of benefits it provides.[35] To address this issue, FERC has passed orders requiring applicable markets consider non-generation resources such as energy storage and demand response for providing ancillary and grid services. These orders allow providers of storage technologies to be fairly compensated for those services.[36]

On the state level, California is actively promoting energy storage deployment and currently subsidizes battery installations at approximately $1.6/Watt with a Self-Generate Incentive Program. The California Public Utilities Commission (CPUC) has also established an energy storage mandate that requires the state's utilities to procure 1.3 GW of energy storage by 2020.[37] Southern California Edison has already begun work to meet this requirement by procuring 261 MW of storage, including a total of 235 MW of battery storage.[38] San Diego Gas & Electric has also made investments and now has 79 MW of energy storage,[39] and Pacific Gas & Electric has contracted for another 75 MW.[40]

New York has created the New York Battery and Energy Storage Technology Consortium and is introducing incentives, including a planned $2.1/Watt battery storage incentive.[41] This initiative is granted by the state's research and development institution New York State Energy Research and Development Authority (NYSERDA) and major utility ConEdison.[42]

Not to be outdone by these early leaders, Oregon passed legislation requiring utilities to obtain 5 MWh each of energy storage by 2020 and instructing the Public Utilities Commission to develop a methodology for valuing storage.[43]

New Jersey has an incentive program for behind-the-meter electrical storage and several other states have considered regulatory or legislative actions to clarify the role and value of storage and promote its use.[44]

The Southeastern United States has remained absent from large scale energy storage deployments because of a lack of favorable policy and regulatory actions seen in other parts of the United States.

3 The Route: Opportunities for Making LIBs in NC

North Carolina's Clean Energy Economy

North Carolina is well-suited to support a growing LIB manufacturing industry given both its role in the early development of energy storage technologies and the success of its other clean energy sectors. Additionally, the many in-state opportunities for utilization of energy storage make it an ideal place to produce batteries that can be deployed locally.

North Carolina's history in battery storage technology dates back to 1987 when the Crescent Electric Membership Corporation became the first utility in the nation to use batteries to reduce the amount of electricity they needed to generate during times of peak usage. Crescent's 500 kilowatt (kW) battery operated for 15 years, nearly double its 8 year warranty period. Currently, North Carolina is home to several large batteries and microgrid demonstration projects.[45]

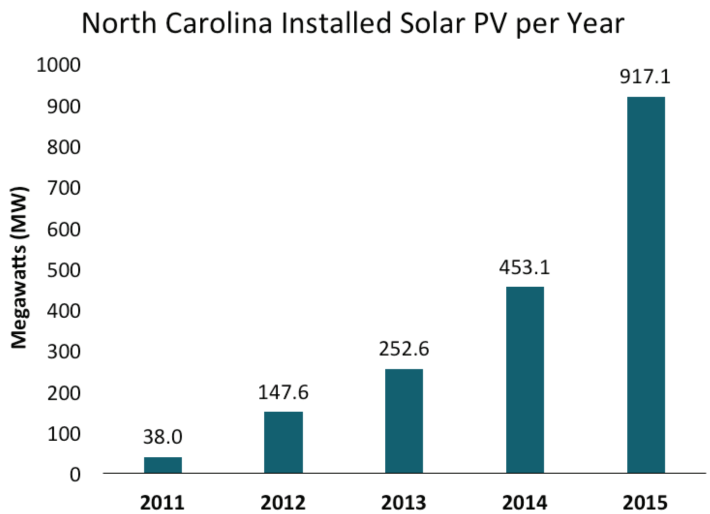

Figure 2. North Carolina Installed Solar PV per Year
Source: NCSEA Renewable Energy Database (July 7th, 2016)

North Carolina's renewable energy market has grown significantly since the state's Renewable Energy and Energy Efficiency Portfolio Standard (REPS) was adopted in 2007, and now boosts approximately 2.3 GW of solar PV, with most of this capacity in the form of utility-scale systems of 5 MW or more in size.[46] In 2015, North Carolina ranked second in the nation for new solar PV installations, and became the third leading state in the nation for cumulative installed solar PV capacity, trailing only California and Arizona.[47] Last year also saw construction begin on the state's first utility-scale wind farm, the Amazon Wind Farm U.S. East. While solar and wind have overcome many barriers to increase their share of the electricity market, they remain intermittent sources when operating alone. Currently, utilities in North Carolina rely upon traditional generating resources to smooth the electrical output of renewable energy systems, but batteries could effectively perform this service with fewer carbon emissions.[48] While battery storage is not a cure-all solution, it can become a valued grid resource that allows for increased integration of renewable energy systems.[49]

The success of solar in North Carolina, particularly utility-scale solar farms, has enabled existing developers to expand, and has attracted new companies to the North Carolina marketplace. This increased deployment of solar in the state has led to the build-out of a supply chain of PV array support structures, such as racking systems, fencing, and wiring suppliers, as well as other allied consulting companies. This type of synergy is possible for LIB manufacturing should demand for batteries in the state increase.

Global and National LIB Production

Despite the progress being made in the U.S., Asian countries continue to dominate the global production of LIBs, with Japan, Korea, and China, accounting for 85% of all manufacturing capacity.[50] These countries have created a strong materials supply chain that has driven down their input costs and allowed them to gain operational expertise.[51] They also enjoy reduced overhead costs because they can fully utilize their manufacturing facilities to produce a variety of products.[52]

Because the U.S. LIB supply chain only accounts for 7% of the global market, and it is relatively new to the industry, the U.S. does not have the same advantages as their global competitors.[53] While it is possible for U.S. LIB manufacturers to succeed, firms will face challenges competing with more established producers. Furthermore, the majority of U.S. LIB production is focused on producing batteries for electric vehicles, and as a result, face the higher performance, safety, and reliability requirements of automotive manufacturers.[54]

North Carolina LIB Supply Chain Opportunities

North Carolina presents a unique opportunity for U.S. LIB manufacturing. At the North Carolina State Roadmap Dialogue, industry leaders and clean energy experts met to identify the strengths and weaknesses that pertain to the North Carolina's clean energy manufacturing industry. Some of the strengths identified were a robust and diverse energy workforce, a large accumulation of research and intellectual property, access to investment capital, the headquarters of Duke Energy, a diverse geographic area, and an eclectic technology and energy economy. Some of the weaknesses identified were an unstable policy landscape, a lack of workforce education, and gaps in the materials supply chain. One of the themes that emerged from the discussion centered on the development of clean energy supply chains in the state. There are some good examples of existing clean energy industries bringing their supply chain to . Strata Solar, for example, entered into a supply contract with mounting system manufacturer, Schletter, which helped to bring manufacturing operations to the state. North Carolina already has some key assets in place for a robust LIB supply chain and may be able to attract additional elements.

Components of the Lithium-ion battery supply chain located in North Carolina include:

> Processed materials, electrodes, and cells are typically the most essential and influential components of the LIB manufacturing value chain. These elements are considered "Critical to Quality" (CTQ); that is, the performance and production output of the LIB are strongly dependent on the elements' purity. Intellectual property and trade secrets surrounding these components often engender competitive advantages by improving the quality of the product. The competitive advantages gained are also not siloed to one particular end-application. The CTQ elements that may have been developed for electrodes in LIB consumer electronics can be transferred to LIB automotive end-applications.
> Source: CEMAC (2015)

Lithium Supply

Rockwood Lithium North America (Kings Mountain, NC)[55]

- Company headquarters
- Site spans 800 acres and contains one of the world's largest spodumene ore deposits
- Produces "battery-grade lithium hydroxide, lithium bromide, lithium chloride, USP-grade lithium carbonate, high purity lithium carbonate, battery-grade metal products, and lithium alloy powders"
- Researches and develops new lithium-based materials for use in batteries within their Global Technical Center and Piloting Operation

Separators

Celgard (Polypore, NC)

- Produces membrane separators for a variety of battery applications, including "rechargeable lithium-ion batteries, disposable lithium batteries, and specialty energy storage"[56]

Anode Materials

Tec-Cel, Inc. (Cary, NC)[57]

- Produces LIBs for end products such as "battery packs for laptop computers, hybrid electric vehicles, wireless smart phones, power tools, and consumer electronics"[57]

Utility-scale batteries

Alevo (Concord, NC)

- U.S. headquarters of the global energy service provider company
- Partners with energy companies to deploy its utility-scale energy storage and smart-grid data analytics technology, GridBank[58]

These existing companies are the cornerstone of North Carolina's developing LIB supply chain and will be key to attracting new firms to the state. Filling the existing gaps in the supply chain will allow for a LIB cluster that could further strengthen the industry through cost reduction, shared resources, and synergies between component manufacturers.

Completing the Supply Chain: End-Use Applications in North Carolina

While deployment of LIBs for electric energy storage in North Carolina is still rare, the state's energy economy presents a strong opportunity for their use. As a state with over 4.2 GW of installed renewable capacity, North Carolina's grid will require active management for additional renewable energy integration; a key application of LIBs. Utilities in the state, including Duke Energy Carolinas, Duke Energy Progress, and Dominion North Carolina Power, are researching the value and applicability of energy storage on the state's grid, as well as implementing several pilot projects and demonstration efforts. North Carolina is home to many large corporate energy users, such as Apple, Facebook, VF Corporation, and New Belgium Brewing, who have already demonstrated a commitment to using renewable energy and reducing carbon emissions, making them prime candidates for distributed energy storage deployment.[59, 60]

Research and Development

Research and development (R&D) of clean energy technologies is crucial to the economic success of manufacturing those products. Breakthroughs in product design, improvements of the assembly and manufacturing processes, developments that improve efficiencies, and other R&D efforts can lead to significant cost reductions increasing the competitiveness of battery energy storage.

North Carolina, home to the "Research Triangle", is well positioned with a thriving research community including universities, government entities, and private sector companies. Several world-class universities located in this research cluster are engaged in the development of cutting-edge clean energy technologies and innovative ways of bringing those technologies to market. For example, NC State University has developed over 1,500 patents worldwide, ranking sixth nationwide for commercialization of university research, while their Industry Expansion Solutions center has generated $3.4 billion in economic benefits for manufacturers in the state since 2000.[61, 62] A strong private integrates well with this academic research. A notable example of this being ABB's work on grid modernization in collaboration with NC State's FREEDM (Future Renewable Electric Energy Delivery and Management) Center.[63] Clusters empower universities, companies, and other entities to benefit from exclusive access to each other's unique expertise, skilled work force, and information leading to increased productivity.[64]

Technology transfer processes at those universities allow private companies to commercialize research from an academic institution, and graduates and collaborators from these universities enhance private sector R&D. North Carolina is home to several of these private companies that are leading the development of technology related to LIBs.[65] The industry may also leverage federally supported activities in R&D, such as the DOE Clean Energy Manufacturing Initiative's work on LIBs for the automotive industry. See Appendix 2 for more R&D projects in North Carolina.

North Carolina's Economic Assets

North Carolina has many attributes that make it a business-friendly environment including a low corporate income tax rate, affordable electricity rates, competitive labor costs, its status as a right to work state, and a favorable legal and regulatory environment.[66] North Carolina's many great natural attributes such as beaches, mountains, and pleasant climate, along with affordable housing, state-of-the-art medical care, and renowned colleges and universities, make it an attractive location for new and existing talent. From a business perspective, there are also many programs and policies in the state to entice and retain businesses, including the clean technology innovation and manufacturing sectors with direct applicability to LIB.

Workforce Development

Along with North Carolina's universities' strong research and development programs, and they produce skilled, knowledgeable, and capable employees. UNC-Charlotte, NC State University, and Appalachian State University collectively offer dozens of degree programs, certificates, and concentrations in energy-related disciplines. For example, the University of North Carolina at Charlotte houses the Energy Production & Infrastructure Center (EPIC), serving the engineering needs of North Carolina's energy economy. EPIC is a public-private partnership with corporations such as Duke Energy, Siemens, AREVA, the Shaw Group and Westinghouse. Additionally, the state's 59 community colleges train students to enter into technical fields and many offer programs in manufacturing or related industrial processes. The Code Green Super Curriculum Improvement Project, undertaken by the NC Community College System Office, redeveloped curriculum related to energy, transportation, buildings, the environment, and engineering to integrate sustainability practices, streamline programs across the colleges, and create stackable credentials for community college students.[67]

A network of supportive career and workforce services builds off this strong curriculum at North Carolina's colleges and universities. Community colleges often host NCWorks Career Centers, which offer career assessment and guidance and job search and application assistance. These centers are coordinated through NCWorks, a statewide workforce development system that partners with employers to provide skill development, training, and employment services.[68] NCWorks also sponsors an apprenticeship program, where employers can work with regional consultants to develop a program that specifies the length, content, and compensation for the training and technical instruction the apprentice receives.[69] All of these aspects of North Carolina's statewide workforce development are utilized in the clean technology space.[70]

Access to Capital

Access to low-cost financing is key for any business, but is especially important for energy storage technology companies that are heavily reliant on capital. North Carolina has several statewide funds for the support of early stage enterprise development, whether that is through investment, grants, or loans. The North Carolina Rural Center, a private nonprofit with some state funding and support, operates programs to encourage businesses and entrepreneurs in rural areas of the state. Its Small Business Credit Initiative works to increase capital availability for small businesses through loan loss reserves, underwriting, and venture capital.[71] The North Carolina Innovation Funds, administered by the North Carolina State Treasurer, invests in companies, funds, and technologies with strong ties to the state.[72]

North Carolina also offers grants and incentives for businesses looking to relocate or expand within the state. For example:

- The One North Carolina Fund (OneNC) - a discretionary cash grant program targeted to competitive job-creating projects, particularly in economically distressed counties;
- The Job Maintenance and Capital Development (JMAC) Investment Fund - another discretionary grant fund targeted towards large employers;
- The Job Development Investment Grant (JDIG) – a program that provides performance-based, sustained annual grants for periods of up to 12 years; and,
- The Industrial Development Fund (IDF) - a grant that fund infrastructure projects expected to lead to job creation.

Since 2007, these programs have provided over 674 awards totaling approximately $1.3 billion.[73]

Transportation Infrastructure

Transportation is an important consideration for any business because of how it dictates the flow of supplies and products. North Carolina is connected to both the country and world through a network of over 90,000 miles of state-owned highways, the largest consolidated rail system in the U.S., four international airports – including Charlotte-Douglas International Airport, the fifth busiest airport in the nation—, and two deep-water seaports – Morehead City and Wilmington. In 2014, North Carolina increased its transportation funding by $700 million for the next two years and approximately $1.6 billion over the following ten years for new transportation construction projects.[74]

4 Potential Roadblocks: Barriers to Deployment and Manufacturing

Despite the potential for energy storage, and particularly LIBs, to provide valuable services to grid-operators and electricity end-users, it has encountered several barriers to deployment and production in the U.S. and North Carolina.

Barriers to Deployment

In 2015, NCSEA released a report detailing the barriers to deploying batteries on the electricity grid. That report, *Batteries Not Included*, provides the basis for this section and describes five similar categories of barriers facing battery integration today: modeling, technological, financial, market, and regulatory.[75]

Modeling Barriers

Modeling: Utilities construct complex models to help them plan the resources needed to meet customer demand going forward. However, incorporating batteries into these models is difficult because of the difficulty in quantifying the diverse benefits batteries provide.[76] Models that better incorporate the costs and benefits of energy storage are under development, and will be necessary to efficiently integrate batteries into the grid.[77]

Technological Barriers

Industry Acceptance: Utilities and regulators have had limited exposure to battery projects, and are not yet familiar with their function and benefits. This lack of experience creates a reluctance to employ a technology that they do not fully understand, and subsequently slows the advances in technology and reductions in soft costs.[78]

Validated Performance: The lifetime performance and longevity of batteries will be important metrics in establishing the business case for their widespread implementation. However, several barriers to communicating battery performance still remain:

> *"Data is necessary to validate the performance, benefits, and lifespan of batteries, and demonstrations, pilot projects, and large-scale installations are necessary to obtain this data. This barrier is further complicated by the lack of a uniform industry standard practice for measuring battery performance."*[79]

Technology Maturity: Although researchers and developers are continually improving battery technology, there are still advancements needed to improve efficiency and scaling the technology to commercial- and utility-levels.[80]

Financial Barriers

Cost: One of the most common arguments against the deployment of batteries is their high cost, but their actual costs are difficult to determine because it is not know exactly how long some batteries will last, and what the costs for hardware like inverters will be going forward.[81] The upfront capital investment required for batteries, combined with this challenge in calculating total-cost of ownership, makes purchase decisions difficult and therefore slows the pace of implementation.

Measuring and Monetizing Value: Stakeholders, accountants, and end-users face difficulties in both measuring and extracting value from batteries because a single monetary value does not typically take into account the full capability of the technology. Batteries are able to 'stack' services, which means they can perform a variety of beneficial services simultaneously, making it hard to determine exactly how much they should be paid for each task. All aspects of battery utilization must be considered in order to adequately value the technology as a whole; as of today, there is no consensus on the true value batteries can provide.[82]

Market Barriers

Market Design / Business Model: Independent battery owners currently face markets that are not well designed for incorporating the technology, or worse, do not have a market available to them. Opening up market opportunities for batteries would allow owners to be compensated for all the services that they can provide.

According to the Batteries ~~Not~~ Included report:

> *"access to a market would allow battery owners to earn a greater return on their investment. However, the design of such a market is complicated by the fact that batteries can stack services. In jurisdictions that require a minimum capacity of generation to participate in the market for ancillary services, market design is further complicated for owners of distributed batteries because in most cases they must aggregate services to participate in the market."*[83]

New market designs must be unlocked in order to expand the capacity for the battery industry.

Regulatory Barriers

General Regulatory Barriers: "Procedural issues, such as slow adoption of new regulations, [and] discrepancies in regulations between various markets" that are some of the examples of the general regulatory barriers that face batteries today.[84] Also, the lack of standards and models caused by limited amount of data and immaturity of storage technologies make it difficult to develop and integrate reliable, high-performing technologies.[85]

Classification: Forcing batteries to fit into a traditional category of grid resource can be difficult and also limit the markets to which owners can sell their services. "In deregulated markets, assets must be classified as generation, transmission, or distribution to allow participation in the appropriate wholesale market. However, batteries are capable of providing services to all three markets."[86] New market classifications may be needed for storage resources to allow their participation in multiple markets and fully realize their value.

Jurisdiction: Discrepancies in regulations, which are more prevalent when businesses or utilities operate across multiple states, represent another barrier.[87] However, "these jurisdictional barriers are present for most aspects of energy regulation and are not unique to batteries."[88]

Barriers to Manufacturing

Chemical Mining Supply: Lithium-ion batteries have become the most common battery technology for personal electronics and EVs.[89] The total number of EVs exceeded 1.3 million in 2016 and sales of EVs are expected to increase rate due to technological innovations that enable manufacturers to offer less expensive electric vehicles with greater driving range.[90] Barriers to fulfilling the growing demand for EVs are more likely to arise from supply shortages of cobalt and nickel than lithium.[91] Approximately half of the current global cobalt supply originates in the Democratic Republic of Congo (DRC), which has a long history of conflict and unstable government. Should the DRC end up in another internal conflict, there could be significant impacts on the supply of cobalt. Nickel has a more diverse global supply, but is still subject to supply shortages. Indonesia banned exports of nickel in January 2014, causing a drastic increase price on global markets from $13,000/ton to $21,000/ton.[92]

Supply and Demand in the Automotive Industry: Within the U.S., 92.5% (4,600MWh out of 4,970MWh) of the total LIB manufacturing capacity is focused on automotive LIB manufacturing.[93] Tesla's Gigafactory, currently under construction in Sparks, Nevada, is expected add an additional 35 GWh, increasing LIB production capacity nearly eight-fold by 2020.[94] This will give the U.S. greater capacity than was available worldwide in 2013.[95] The price of LIBs is a critical factor needing to be addressed in order to achieve lower EVs costs. The economies of scale and improved efficiency from the design of the Gigafactory is expected to allow Tesla to deliver its Model 3 vehicle at a more affordable price.[96] Increased production of LIB will result in lower prices, and as a result, increase their demand. This is already evident in pre-orders of Tesla's Model 3, which is currently priced at $35,000 dollars, and expected to be released in 2017. As of May 2016, 373,000 Model 3s had already been ordered, which, according to the U.S. Energy Information Administration (EIA), is about 45 times greater than the total number of EVs in the U.S. in 2014.[97, 98]

5 Shortcuts: Addressing Barriers through Strategic Opportunities

Aside from filling in gaps along the supply chain, the LIB industry currently faces challenges with product demand, valuation, regulation, and industry standards. This section focuses on possible opportunities to address these types of barriers through industry action.

Industry Working Groups

NC Sustainable Energy Storage Working Group: NCSEA has identified the need for a collaborative dialogue on how North Carolina deploys energy storage. North Carolina has a strong and growing energy storage cluster and an interested base of customers looking for its adoption. In light of national and international storage deployments, favorable technological properties, declining costs, and robust future projections, North Carolina must develop a set of regulatory "rules of the road" that allow energy storage to be utilized for all of its possible purposes.

To that end, NCSEA created an Energy Storage Working Group in April 2016, which includes the investor owned utilities, the rural electric cooperatives, universities doing research on energy storage solutions, the NC Utilities Commission Public Staff, energy storage companies, and other stakeholders. The working group's goals and targeted outputs are as follows:

- Identify existing regulations that are applicable to energy storage;
- Identify gaps in those regulations where additional guidance is necessary to deploy storage;
- Produce a document from the working group meetings that outlines the challenges and possible solutions to govern storage deployment in North Carolina. The list of challenges to overcome will allow the industry to conduct transactions and scale business.

If North Carolina can solve the challenges outlined by the working group, the expected outcomes are expanded markets for storage technologies and new economic benefits to North Carolina.

These types of convenings are critical to advancing the common interests of multiple firms acting in the same market. Associations build relationships, foster communication and coordination among key stakeholders, identify common and urgent needs, share information, lobby for beneficial policy changes, and more.

Industry Standards

The formulation of standards and best practices can address the technological barrier of industry acceptance and foster understanding of LIBs. Publishing standards for battery testing and performance will reassure end-users and regulators that products meeting those standards are safe and reliable. Collaborating with utilities and regulators to create consistent standards for utility cost recovery of energy storage assets may also increase utility procurement of batteries and their appearance in integrated resource plans.

Defining the Value of LIBs

An accurate understanding of the value energy storage provides is critical to the development of regulations and appropriate compensation for the use and ownership of LIB assets. Energy storage stakeholders must work to develop methodologies that properly defines the value LIBs add to the electricity grid and allows users and developers of LIB systems to fully capture the value of their investments. Efforts to examine of the value of energy storage are currently underway in Oregon, where the Public Utilities Commission has opened a docket to implement an energy storage procurement program.[99]

Pilot and Demonstration Projects

Pilot and demonstration projects are an important way to demonstrate the viability of LIBs for electrical energy storage applications. These projects may be used to test the performance, cost, and savings of the various use cases for LIBs, and help determine best practices for the utilization of energy storage. Utilities in North Carolina have already launched a number of energy storage pilot projects, but are continuing to adjust their programs to test new technologies and applications. Regulated utilities are frequently unable to attain cost-recovery for such programs, though permission to do so would likely increase their willingness to undertake these research and development efforts, strengthening the business case for grid-scale battery deployment.

Identify Industry Needs and Strategies

Finally, additional opportunities to grow the LIB market may exist throughout the value chain. These opportunities may include identifying key commercialization research needed and the partnerships that could provide it (i.e.- universities, U.S. DOE), focusing workforce development resources on engineering and coding skills for robotics and manufacturing, and finally creating a thorough supply chain map of existing LIB businesses in North Carolina and the Southeast.
Table 1 summarizes the key LIB market barriers and proposed solutions needed to address them. The solutions presented here focus on actions industry stakeholders can make directly, without legislative or regulatory changes. There are a number of policy changes that could improve economic opportunities for LIBs, but they are beyond the scope of this report.

Barrier	Solution(s)
Modeling	Pilot programs
Industry Acceptance	Formation of industry association and relationship building with related industries
Validated Performance	Standards
Technical Maturity	Commercialization research
Cost	Commercialization research, industry association to address “soft costs”
Measuring and Monetizing Value	Workgroup to study storage valuation and develop methodology
Supply Chain	Inventory of existing businesses and supply chain mapping
Industry Recruitment	Collaboration with economic development authorities to promote NC’s assets in R&D, workforce, low cost of business

Table 1: Addressing Barriers through Proposed Solutions
Source: Alternative Fuels Data Center, updated June 7, 2016.

6 Destination: A Thriving LIB Manufacturing Sector in North Carolina

North Carolina's historical strength of clean energy manufacturing is aided by a friendly business climate consisting of low corporate income tax rates, affordable electricity rates, competitive labor costs, and a favorable legal and regulatory environment. North Carolina also has a strong education system with research and development opportunities at specific to LIB development. All of these factors make the state an attractive place to locate and grow LIB manufacturing operations. In addition, as North Carolina accommodates more solar energy generation and large energy users explore the benefits of behind-the-meter storage, the state should see increased energy storage deployment in the near future.

North Carolina is particularly suited to focus its energy storage industry on manufacturing LIBs. The state is home to several anchor companies in the supply chain such as Alevo, Celgard, and Rockwood Lithium, presenting an opportunity to realize the cluster benefits of several companies providing related services and products. However, the barriers identified in this roadmap including those associated with modeling, technology, financing, market design, and regulatory framework will require a concerted effort to overcome. Local industry stakeholders are discussing ways to overcome them through the NCSEA Energy Storage Working group. In addition, North Carolina is awaiting the results of pilot programs, the development of industry standards, and commercialization of new research. In the future, a comprehensive inventory of supply chain assets and gaps, along with this document that outlines the market, economic, and other strategic assets for LIB manufacturing in North Carolina, will be useful in attracting new businesses to the sector.

Appendix 1: Batteries & the Electricity Grid: Specific Benefits

Benefits to Utilities and Grid Operators

Electric Energy Time-Shift: Energy storage systems allow their owners to make a profit by purchasing inexpensive electricity when the prices are low and reselling it when demand and prices rise. This is often referred to as arbitrage, but differs from the traditional financial definition, because the purchase and sale of the commodity do not occur at the same time.[100]

Electric Supply Capacity: In areas where there is insufficient generation capacity to meet the highest levels of demand, energy storage systems can be used to defer, or even eliminate, the need to purchase a new central generating station, such as a natural gas turbine. There are different market mechanisms for determining the revenue of these resources, with some being paid for capacity even if it is not used, while others recoup costs in payments they get for energy sold.[101]

Electric Supply Reserve Capacity: The North American Electric Reliability Corporation (NERC) sets standards for the reliable operation of the electricity grid and requires that grid operators maintain reserve capacity, or resources that can be utilized should one or more generation resources go off-line unexpectedly. These are often categorized as spinning reserves or supplemental reserves based on how quickly they can begin supplying power to the grid. Energy storage can provide these services and when charging can even provide twice the reserve capacity, since it can both stop charging and start discharging almost immediately.[102]

Transmission Support: The unique attributes of energy storage, particularly batteries, make them well suited to providing a variety of complicated transmission services that can improve system performance and produce a more stable electricity grid. These services involve "compensating for electrical anomalies and disturbances," and increasing the amount of electricity that can be sent over transmission lines.[103]

Transmission Congestion Management: Similar to energy time-shift capabilities, energy storage can mitigate the need to send electricity over congested transmission lines at times of high demand. By locating and energy storage system near a load center, it can be charged during times of low demand and provide local production at times of high demand when electricity would otherwise need to be sent over crowded transmission lines.[104]

Avoided Transmission and Distribution Energy Losses: Batteries offer the ability to minimize and avoid energy losses during transmission and distribution. The transmission and distribution of energy incurs losses as the energy is transferred. These losses are highest at high temperatures and heavy loads. Storage can reduce these losses by charging at night and off-peak hours and avoiding the delivery of grid energy during high temperatures and peak demand periods. Avoiding this strain on transmission and distribution infrastructure can also prolong the life of the equipment and delay the need for upgrades.[105]

Renewable Capacity Firming: Renewable energy generating resources often have intermittent output, meaning that the amount of power they produce can change on both a short (seconds to minutes) and long (over the course of a day) time-scale. Energy storage, particularly batteries, can be used to fill-in the gaps in production by renewable energy resources, as well as reduce the need for load-following resources when resources, such as wind and solar, are going off-line.[106]

Benefits to Customers

Time-of-use Energy Cost Management: Battery storage can reduce electricity end user's time-of-use (TOU) energy cost by charging with low-priced energy to be used later when energy prices are high, resulting in overall cost reduction. This may be especially beneficial to customers with distributed renewable energy systems as energy storage would allow them to store self-generated energy for use at times of higher rates.[107]

Demand Charge Management: Demand charges are incurred by large electricity customers for the additional infrastructure needed to meet their demand. Charges are based on the highest demand, in kW, of a customer during a billing period and are addition to energy charges measured in kWh. Batteries can help reduce these costs by limiting the amount of power these customers draw from the grid during their periods of highest use, essentially flattening their demand curve and reducing their highest kW demand.[108]

Backup Power: Batteries can also improve electric service reliability by providing on-site backup power that could be utilized in the event of a grid-failure. Loss of electrical services often means stopping work and reductions in productivity. With a backup energy storage system, these financial losses can be avoided by discharging stored energy during the outage.[109]

Appendix 2: Research and Development in NC

Universities, such as UNC-Chapel Hill, North Carolina State University (NCSU), and Duke University, are conducting research to improve LIB technologies. The DeSimone Group, a chemistry lab at UNC-Chapel Hill, is conducting research to improve the cycling and efficiency of batteries using their prototype electrolyte, resulting in safer, higher energy batteries in the future.[110]

Researchers at NCSU are focusing on materials that function as semiconductors for use in LIBs, solar cells, and other applications. The development could allow batteries to store more energy due to a greater surface area in their structure, which could result in significantly increased capacity for lithium ion batteries.[111]

The FREEDM Systems Center, an engineering research center housed at NCSU, focuses on developing an advanced green energy grid infrastructure. The Center is part of an innovative strategic plan to invite collaboration across universities, industry, and the public sector on both fundamental research and technology development. Researchers at the FREEDM Systems Center have made key advancements in battery technology, including the development of carbon nanofibers that improve the energy and power densities, charging speed, life cycle length, fabrication, cost, and environmental impact of LIBs.[112] The Center also focuses on distributed energy storage devices (DESD) and the integration of those devices with the grid.[113]

Duke University is home to the Energy Initiative and the Center on Globalization, Governance, and Competitiveness, both of which have performed research on energy storage technology.[114, 115] UNC-Charlotte's Energy Production and Infrastructure Center (EPIC) in the College of Engineering published research on battery energy storage system management.[116] North Carolina universities have also been a key resource in supporting technologies through research in economics, policy, and related fields.

The university-led research in North Carolina, however, does not remain in an academic silo, and has strong connections to the market and real-world applications. NCSU, for example, has facilitated strong partnerships between its academic centers and private industry. The Supply Chain Resource Cooperative in the Poole College of Management supports students, faculty, and corporate partners through services, programming, and thought leadership.[117] The Entrepreneurship Initiative supports student innovation and entrepreneurship through staff support, workspace, networking trips, and events.[118] The university's Industry Expansion Solutions center offers assistance and strategies to businesses in the state aimed at lowering costs, improving products and processes, and helping them to innovate and grow. It serves as the state's Manufacturing Extension Partnership as designated by the National Institute of Standards and Technology (NIST). It also administers Manufactured in North Carolina, a supply chain tool that provides a comprehensive database of products made in North Carolina, as well as the mfgNC a Connections program, which works to build connections between manufacturing firms in the state.[119]

University Technology Transfer

The state's universities are also leaders in bringing new technologies and products to market. In 2013 alone, the UNC system (NCSU, East Carolina University, and UNC-Chapel Hill, UNC-Charlotte, and UNC-Greensboro) issued 196 licenses or options for technologies, brought in $10.7 million in licensing revenue, and issued 85 U.S. patents.[120] NCSU has over 100 spinoffs and startups that have raised approximately $1.6 billion in venture capital,[121] and over 80 companies have started out of UNC-Chapel Hill.[122]

Technology Transfer Processes

Technology transfer policies and protocols can have a significant impact on how quickly and widely a new technology may be commercially available. The process of moving emerging technology from development stages to market is often hindered by gaps in financing, demonstration, or other resources, known as the "Valley of Death." Successful technology transfer protocols can help bridge the valley by facilitating pathways to marketing and monetizing the technology, partnerships between technology creators and users, and processes that protect the interests of both.[123]

Universities face the challenge of balancing expediency with adequate intellectual property protection. Universities typically have an office dedicated to evaluating and licensing innovations they develop. These offices help researchers and inventors at the university assess the market potential of the research product, file for intellectual property protection, engage in licensing negotiations, and often establish partnerships with industry to successfully commercialize the product.[124]

Licensing agreements must also balance the needs of users and creators. Creators need to receive enough revenue from licensing agreements to justify the time and expense of both developing the product and making the deal with the user. The user wants to minimize fees and costs associated with the license to mitigate risk and make developing the end product worthwhile. As with most policy arenas, standardization in licensing agreements can help both parties better predict the arrangement and streamline licensing negotiations. To agree on fair royalty rates, some industry members have advocated for low standard payments with "windfall clauses" that would provide profit sharing in the case of a highly successful product.[125]

UNC-Chapel Hill has developed the Carolina Express License Agreement, a fast-tracked process for commercialization. The express licensing process allows developers looking to start a company from a new technology product to utilize a standardized Express License that outlines company ownership, future revenue payments, and other common provisions.[126]

At NCSU, the Chancellor's Innovation Fund also provides additional support to researchers and innovators at the University to strengthen the commercialization of new technologies, by specifically targeting key license-enabling milestones. [127]

Private Sector Research

Universities are not the only entities producing valuable research and development. North Carolina is home to several private companies developing cutting edge technology, including applications relevant to LIBs.

ABB, a multinational company for power and automation technologies, has a Corporate Research Center located on NCSU's Centennial Campus in Raleigh, NC. The physical location has allowed ABB to foster relationships with NCSU and to collaborate with university researchers. The company's research focus areas include transmission and distribution system engineering, grid modernization technologies, and other advanced engineering with implications for LIB technologies.[128]

Celgard, a leading company producing membrane separators for energy storage applications, has R&D facilities located in Charlotte, NC. Celgard's innovations in separator solutions and coatings address battery performance, cycling, safety, energy density, and flexibility for various electrochemical cell configurations.[129]

The state also has several incubators and accelerators that support early stage companies in clean energy. CLT Joules is an initiative based in Charlotte to provide clean energy startups access to resources, including business model planning, financing, work space, and other tools.[130]

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