Next-Generation Energy

Report to the North Carolina General Assembly

March 15, 2025

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Contents

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Legislative Charge

North Carolina is leading the way in driving the energy transition by fostering economic development, catalyzing new jobs and industries, and actively harnessing its critical natural resources to support this transition. The State is leveraging its significant intellectual capital to solidify its position as a leader in the energy sector.

Over the past several years, the North Carolina Collaboratory has played a pivotal role in advancing North Carolina's energy sector. Its initiatives have encompassed supporting research on mineral extraction, promoting efforts to enhance grid resilience, and exploring the potential of advanced nuclear and hydrogen energy technologies.

This report is designed to provide a brief update on the Collaboratory's current projects related to energy issues and outlines some future plans to encourage innovation in the sector across North Carolina.

In the 2023 state budget (Session Law 2023-134), the North Carolina General Assembly invested $15 million for next-generation energy research.

These funds are intended to identify and execute research that will assist industry efforts in the energy transition as well as take advantage of the subsequent economic development opportunities.

Several projects funded by the Collaboratory align directly with the recommendations outlined in the Energy Policy Council's 2024 Biennial Report, which highlights the specific technologies and workforce development programs required to advance North Carolina's clean energy economy.

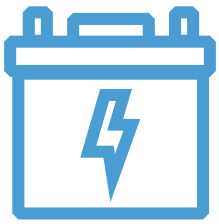
The legislation requires the Collaboratory to report on its progress to the Joint Legislative Education Oversight Committee by March 15, 2025, and annually thereafter while funds remain. The submission of this written report is intended to meet that legislative requirement.

Photo by Matthew Henry on Unsplash

By the Numbers

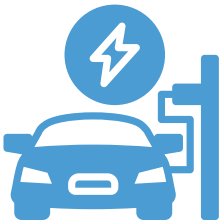
$2B

Estimated annual economic impact from Piedmont Lithium & Albemarle mines.



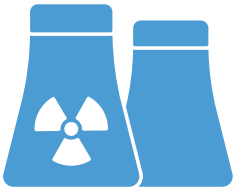
4,200+

storage and grid modernization jobs in NC - 10th largest workforce of its kind in the nation.



48%

of NC's vehicle fleet has the opportunity to be electrified, according to National Renewable Energy Laboratory

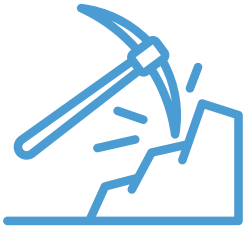


$4.8B

Total annual economic impact of the nuclear industry on NC according to E4 Carolinas.

$1.4B

Investment by Natron Energy to establish a sodium-ion battery gigafactory in Edgecombe County.



80%

of the known lithium reserves in the U.S. are found in Cleveland and Gaston counties, per the Department of Environmental Quality.

$150

Per person loss estimates of power outages from natural disasters, according to the Federal Emergency Management Agency.

1.5M

Residents in western NC without power due to Hurricane Helene.

Partnerships Leveraged

The projects funded by the Collaboratory as part of this research portfolio have resulted in building new partnerships and collaborations across industry, academia, and governmental and non-profit organizations.

Industry Partners

Highland

HITACHI

PINE research

PIEDMONT LITHIUM

DUKE ENERGY®

Minerva Lithium Nano Mosaic

Academic Partners

WAKE TECH COMMUNITY COLLEGE

CAPE FEAR COMMUNITY COLLEGE

UNC CHARLOTTE
Energy Production and Infrastructure Center (EPIC)

NC STATE UNIVERSITY

UNC GREENSBORO

Appalachian STATE UNIVERSITY

Duke UNIVERSITY

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Governmental & Non-Profit Partners

NORTH CAROLINA DEPARTMENT of COMMERCE

Public Staff
North Carolina Utilities Commission

NORTH CAROLINA Environmental Quality

E4Carolinas®

NCBCE
Invest • Inspire • Innovate

CITY OF WILMINGTON NORTH CAROLINA

INSTITUTE OF DIGITAL ENGINEERING USA

CITY OF RALEIGH NORTH CAROLINA

EPRI

NC

Opportunities in Mineral Mining & Commercial Development

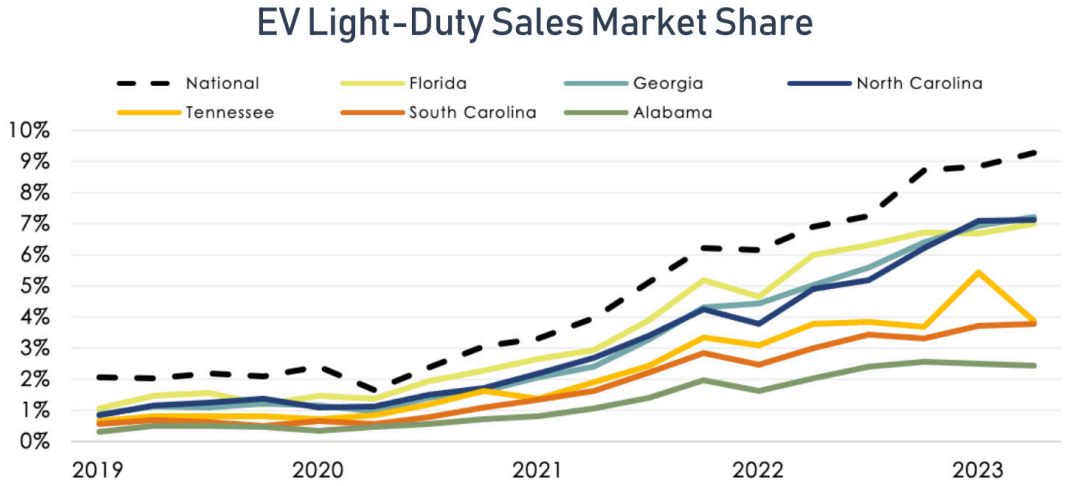
North Carolina's abundance of lucrative minerals has attracted many companies across the battery value chain to the State. Together, the proposed mines of Piedmont Lithium and Albemarle Corporation have the potential to generate an annual economic impact of $2 billion.

In 2023, Albemarle proposed to expand its efforts by establishing a $200M lithium center in Charlotte's University Research Park. This incentivized Toyota to deploy its first North American electric vehicle battery facility in Randolph County – the plant is anticipated to generate ~5,000 jobs.

As of August 2024, Natron Energy, the sole commercial manufacturer of sodium-ion batteries in the US, announced plans to invest $1.4 billion in establishing a giga-factory in Edgecombe County. This facility is expected to generate more than 1000 jobs with average wages of $64,071 – significantly higher than the county's mean wage of $43,183.

Mike Walden, PhD, North Carolina State University (NCSU), concluded that North Carolina can "contribute to a domestic source of lithium while creating millions of additional tax dollars," underscoring the importance of the battery sector to our local economy.

Per the Department of Energy, North Carolina saw a 47% increase in electric vehicle sales, with annual fuel savings of $1,700 for trucks and $1,200 for passenger vehicles between 2022 and 2023. The demand for clean transportation is clear, and North Carolina has the natural resources and emerging industry leaders to leverage these opportunities and innovate solutions to meet the State's energy needs.



This figure depicts EV sales as a percentage of light-duty vehicle sales from 2019 through June 2023. The jump in new EV sales in Tennessee in Q1 of 2023 is an outlier for unknown reasons. Source: Atlas EV Hub

Advancing Research in Critical Minerals and Battery Technology

The Collaboratory is dedicated to improving the mineral market in North Carolina by backing initiatives such as the research of Drew Coleman, PhD, at the University of North Carolina at Chapel Hill (UNC-CH). Coleman has been utilizing a cutting-edge technology called laser-induced breakdown spectroscopy (LIBS), which has shown significant advantages for industrial use, especially in evaluating ore quality with advanced aging techniques. Additionally, Hemali Rathnayake, PhD, at UNC Greensboro has tested an alternative technology, the Nano Mosaic SPE, which she found enhances extraction efficiency by up to 87% and reduces acquisition time to just 48 hours.

At the same time, Adam Curry, PhD, at NCSU is working on several simultaneous projects related to lithium pegmatites in North Carolina, including a detailed study of the mineral's stable isotopes, geochemical analysis of potential parent rocks, including nearby granites and metasediments, and ongoing work on the geochronology of the lithium pegmatite system.

A research initiative beginning in 2025, led by Professor Daniel Richter at Duke University who specializes in soils and forest ecology, will explore the presence of lithium-rich deposits from a pedological and geomorphological standpoint. The study draws inspiration from Rathnayake's work, and seeks to assess the origins of surface lithium traces derived from deep-seated lithium-rich pegmatites.

Walden's research not only encompasses lithium and phosphate reserves in the state, but also emphasizes the economic prospects linked to high-purity quartz. Mitchell County, the top global producer, yields an estimated annual value of $700 million from this resource. Thanks to the ongoing collaboration between researchers, local authorities, entrepreneurs, and industry leaders, North Carolina continues to play a crucial role in the battery supply chain.

Considering the exponential growth of the battery and energy storage supply chain in North Carolina, Jamie Russell, PhD, at Appalachian State University (ASU) proposed the development of a sectoral partnership. This nexus would foster communication between industry members across all areas of the battery life cycle, from mineral extraction to downstream services such as recycling and battery management software. The partnership will focus on filling workforce gaps, developing new technologies, expanding markets, and identifying policy needs.

The goal is to promote productivity and efficiency by allowing those within the regional supply chain to leverage each other's services and collaborate on projects. Russell also plans to produce a public supply chain database where companies can publish relevant information about supply needs and points of contact.

Daniel Richter, PhD, at Duke Nicholas School of the Environment, Professor of Soils and Forest Ecology

Mike Walden, William Neal Reynolds Distinguished Professor and Extension Economist at NCSU

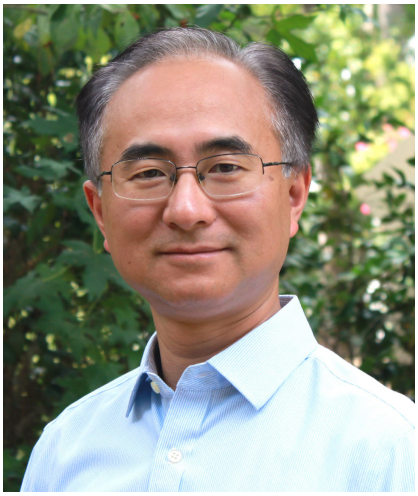
Advancing Research in Critical Minerals and Battery Technology Continued

Wei You, PhD, at UNC-CH and his team are poised to harness North Carolina's stronghold in critical minerals and processing capacity by establishing the UNC-CH Center for Energy Storage. This center aims to connect fundamental science with advancements in more sustainable lithium-ion battery technology. Its goal is to enhance the safety and stability of next-generation battery materials by pioneering new classes of carbon-based, solid-state lithium-ion batteries.

This research addresses two key concerns: the rising demand for energy storage as renewables are added to the grid and the overreliance on scarce, costly, and potentially harmful materials currently used in lithium battery designs.

Paige Ouimet, Professor of Finance and Executive Director of UNC-CH's Kenan Institute of Private Enterprise, is evaluating the potential market size of three critical energy-related minerals: silica, lithium, and phosphate. These minerals are essential for the battery value chain and the semiconductor industry, both of which play a vital role in many renewable energy technologies.

Ouimet's research team aims to assess the feasibility of a proposed severance tax as a mechanism to generate additional state funding for energy projects, infrastructure development, education, and other initiatives.



Wei You, PhD, Professor of Chemistry and Applied Physical Sciences at UNC Chapel Hill

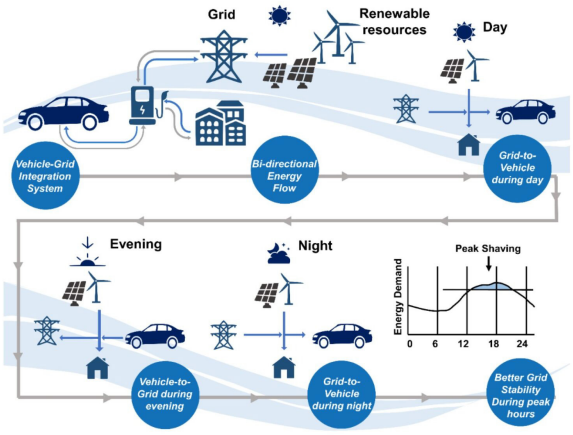
Paige Ouimet, Professor of Finance and Executive Director of UNC Chapel Hill's Kenan Institute of Private Enterprise

Strengthening Grid Resilience

The Collaboratory's next generation research portfolio includes four projects to address grid security and stability.

V2G/V2B Capabilities

The first project, led by Noah Kittner, PhD, at UNC-CH, is exploring the potential for implementing emerging vehicle-to-grid (V2G) and vehicle-to-building (V2B) technologies for North Carolina's municipal fleets. Kittner and his team aim to evaluate storage capacity, map current and planned electrified municipal fleets, and identify opportunities for bidirectional energy transfer. The expectation is that these fleets will then not only draw from the grid, but also supply energy back during emergencies, helping to stabilize electricity resources.



How V2G/V2B technology works (Image: MDPI Energies)

The Co-Simulation of Transmission & Distribution

Robert Cox, PhD, at UNC Charlotte is leading the second project, which aims to streamline the planning and operation of generation, transmission, and distribution infrastructure. Informed planning is critical as the addition of renewable energy sources increasingly decentralizes the grid.

Cox and his team will partner with the Energy Production and Infrastructure Center (EPIC) and Duke Energy's Center for Advanced Engineering Research (CAPER), to create a co-simulation tool to model a future, carbon-neutral grid. The tool will integrate intricate scenarios and simulate the future dynamics of the entire Eastern Interconnection to promote efficiency and reliability.

Energy Storage Landscape

Gregory Copenhaver, director of UNC-CH's Institute for Convergent Science, will lead a study that provides a state-wide assessment of the economic landscape, technological and resource availability, and academic research related to energy storage projects in North Carolina. This initiative aims to advance the industry, attract potential businesses with energy storage needs, and provide science-based guidance to policymakers on such storage projects to enable grid stability and security amid an increasingly renewable electric grid.

Additionally, Alexander Miller, PhD, at UNC-CH, is leading a project in collaboration with UNC's Sustainable Energy Research Consortium that adopts a hands-on approach to advancing battery storage development. The project aims to establish a fully operational and adaptive battery fabrication and testing facility designed to meet North Carolina's battery research needs for years to come.

Lessons from Hurricane Helene on Grid Resilience

Hurricane Helene's devastation of western North Carolina resulted in tremendous loss of life, and destruction of property and infrastructure, including significant impacts to the electric grid. As of mid-October, areas of western North Carolina remained without access to power, essential services, and transportation options. Duke Energy made significant efforts to restore power to over 90% of customers in upstate South Carolina and several counties in western North Carolina. However, damaged infrastructure, overstretched emergency responders, and limited transportation access have hindered relief efforts in the hardest hit and most remote areas.

The Collaboratory is firmly committed to assisting in recovery efforts and advancing research on grid resilience to mitigate the impacts of future natural disasters.

The innovative research of Copenhaver, Kittner, and Cox is actively contributing to grid resilience efforts.

Furthermore, newly funded studies set to begin in 2025, led by Jordan Kern, PhD, and Benjamin Rachunok, PhD, at NCSU, will leverage machine learning algorithms to enhance weather forecasting and predict power outages caused by physical and cybersecurity attacks. The study led by Kern will utilize optimization tools to help utilities, such as Duke Energy Carolinas, enhance resource allocation, reduce vulnerabilities to targeted attacks on critical grid infrastructure, and streamline recovery efforts.

The Collaboratory seeks to bring actionable solutions and enhance data on risk management and mitigation to strengthen grid resilience.

Deployment of Advanced Nuclear Reactors

North Carolina's need for low-carbon, baseload energy sources has renewed interest in expanding advanced nuclear fleets as fossil fuels are phased out. The five nuclear power plants currently operating in North Carolina, coupled with other facilities in neighboring states, have built a robust regional nuclear workforce training and qualification network. However, this workforce has experienced significant shifts based on workforce attrition, cost reductions, generational differences, and evolving technologies. To support the future fleet of advanced reactors, including new technologies such as small modular nuclear reactors (SMRs), this workforce network must expand not only in size, but also in skills, knowledge, and practices. The Collaboratory is supporting two projects at NCSU that focus on preparing the next workforce generation to meet changing construction, operations, and maintenance needs.

Defining Advanced Reactor Workforce Needs

Kostadin Ivanov, PhD, head of the Department of Nuclear Engineering at NCSU, has launched a partnership with the non-profit organization Electric Power Research Institute (EPRI) to investigate the education and skill requirements necessary for the construction, commissioning, testing, operation, and all other critical functions of a nuclear facility. They will utilize the test reactor at NCSU to identify knowledge gaps and guide the development of comprehensive and effective training programs. Additionally, they plan to collaborate with stakeholders, including K-12 schools, community colleges, universities, and industry partners, to strengthen workforce pipelines, thus enhancing the safety and efficiency of nuclear operations and boosting local economies.

Boiling Water SMR Simulator

As North Carolina looks towards SMRs as a potential source of energy generation, Maria Avramova, PhD, and her team at NCSU have identified a key challenge: communicating about a new nuclear technology without compromising intellectual property and US export-controlled information. To solve this issue, Avramova is currently working with GE Hitachi Energy to develop a non-export controller Boiling Water-SMR digital simulator with a non-confidential benchmark that will verify the simulator's accuracy. The simulator demonstrates how the plant operates and responds to changing environmental conditions, and showcases SMR technology concepts such as natural circulation and passive safety. This project provides a strong basis for scientific collaboration on SMR research, education, and training programs, and spurs STEM development in community college technical programs and high schools.

"Our partnership with NC State exemplifies the synergy between academia and industry in driving innovation and educational excellence. This project not only advances SMR technology but also inspires the next generation of nuclear engineers and scientists around the world."

~ Sean Sexstone, Senior Executive at GE Hitachi Nuclear Energy

Kostadin Ivanov, PhD, Distinguished Professor of Nuclear Engineering at NCSU

Maria Avramova, PhD, Associate Professor and Director of Reactor Dynamics and Fuel Modeling Group

Looking Forward: Ideas for Next-Generation Funding

The Collaboratory will continue to support research that promotes the efficient and environmentally conscious extraction of NC's critical minerals, such as lithium, phosphate, mica, feldspar, and more. The Collaboratory plans to expand Curry's research on lithium pegmatites and develop a comprehensive inventory of critical mineral information here in NC. This inventory will include the locations, reserve volumes, and economic estimations of the minerals, a list of historic and active mines, and information on the academic institutions currently conducting critical mineral research.

There are numerous academic institutions dedicated to researching minerals, processing techniques, and downstream applications in the clean energy sector. Some examples include NCSU's Mineral Research Laboratory, UNC-CH's geology and geochemistry labs, and UNC Charlotte's Battery Complexity, Autonomous Vehicle, and Electrification Research Center (BATT CAVE). Beyond critical mineral research, NC is home to many labs pushing innovations in clean energy, such as NC A&T's Center for Energy Research and Technology, ASU's Appalachian Energy Center, and more.

Manufacturing Semiconductors

The ample natural mineral resources in North Carolina present significant prospects for economic expansion, not only within the battery industry but also in other high-demand sectors, such as renewable energy and AI-related projects. Semiconductors play a vital role in enabling a shift towards clean energy by facilitating the harnessing, control, and transmission of electrical currents.

Moreover, the digitalization of the energy sector, coupled with advanced AI-driven software tools for managing and evaluating clean energy capacity, depends on essential raw materials like silicon for optimal functionality. Currently, the majority of semiconductors in the US are imported from Southeast Asian nations such as Vietnam, Malaysia, and Thailand. However, there are substantial opportunities to enhance domestic manufacturing capabilities, and North Carolina has emerged as a pivotal region attracting federal attention for this expansion.

The (Creating Helping Incentives to Produce Semiconductors) CHIPS and Science Act is set to invest a considerable amount, potentially $750 million, in Wolfspeed, a semiconductor manufacturing company based in Durham. This investment aims to establish the world's largest silicon carbide ecosystem, with manufacturing facilities to be built in Siler City, North Carolina, and Marcy, New York. Furthermore, NCSU is receiving additional funding from the White House and Department of Defense through the CHIPS Act to enhance semiconductor research, particularly focusing on projects within the Commercial Leap Ahead for Wide Bandgap Semiconductors (CLAWS) Microelectronics Hub.

In response, the Collaboratory is exploring opportunities to support research at local and regional levels, as well as fostering public and private partnerships to address the growing demand in the semiconductor industry.

Looking Forward Continued

Risk Mitigation and Resilience

Hurricane Helene not only demonstrated the vulnerability of North Carolina's power grid, but also its natural resources. The outskirts of the western North Carolina town, Spruce Pine, are home to two mines which produce the world's purest quartz, an essential component of semiconductor chips and other renewable energy infrastructure. Both Sibelco and The Quartz Corp, who separately manage the mines, had to shut down operations from the start of the storm on September 26th, 2024.

The facilities were fortunate to sustain only minor damages; however, operations and shipments resumed several weeks later. Uncertainty regarding when employees would be able to return, as many dealt with personal losses caused by Hurricane Helene further exacerbated the situation. If these mines had remained offline for an extended period, it could have led to widespread supply chain disruptions, halting production across several industries and driving up product prices.

Thus, greater research efforts must be given to securing and managing risks for key energy infrastructure and assets to ensure long term resilience of the clean energy industry and others dependent on these essential minerals. Fortunately, higher education institutions and research centers across North Carolina are actively advancing this research, focusing on solutions such as microgrids, restructuring urban planning and design to accommodate rising extreme weather events, and enhancing modeling, forecasting, and warning systems to ensure adequate preparation and adaptation measures are implemented.

Green Hydrogen

Hydrogen gas has long been recognized as a promising energy source due to its clean energy properties, dispatchability, and compatibility with existing energy infrastructure. The Energy Policy Council, in its 2024 Biennial Report, highlighted the significance of hydrogen energy—particularly green hydrogen, which is produced through electrolysis powered by renewable energy—in advancing North Carolina's clean energy objectives. However, both nationally and at the state level, a feasibility gap remains, which can be addressed through additional research and development to enable the scaling of the technology and achieve commercial viability.

Hydrogen holds significant potential to reduce the carbon footprint of the transportation sector, particularly in heavy-duty trucks, freight, and the airline industry, which have proven notoriously difficult to decarbonize. While the electrification of fleets and advancements in battery storage technologies will remain key priorities for the Collaboratory, green hydrogen offers unique and innovative opportunities for North Carolina that warrant further exploration.

Looking Forward Continued

Addressing Potential PFAS Contamination in Next-Generation Energy Resources

In developing this next-generation energy portfolio, it is essential for the Collaboratory and researchers across the State to consider the potential chemical contamination risks associated with materials used in lithium-ion batteries (LiBs), certain solar panel coatings and other next-generation energy technologies. Lee Ferguson, PhD, Associate Professor of Civil and Environmental Engineering at Duke University, received funding from the Collaboratory for research on per- and polyfluoroalkyl substances (PFAS). In this research, he and his colleagues identified the presence of a class of PFAS, known as bis-perfluoroalkyl sulfonimides (bis-FASIs), within the electrolytes, separators and electrode binders of rechargeable LiBs. While the environmental and health implications of bis-FASIs released during the manufacture, use, and disposal of LiBs remain largely unknown, it is essential to proactively advance research and develop mitigation strategies.

The Collaboratory is committed to a comprehensive approach that addresses the State's energy challenges while safeguarding the health and well-being of North Carolina's population. To this end, the Collaboratory will fund further research by Ferguson into PFAS contamination in solar panel coatings and other next-generation energy technologies. The findings will be disseminated to the public, policymakers, and researchers engaged in this interdisciplinary field to support the development of effective solutions for managing these risks in the future.

Photo by Andreas Gücklhorn on Unsplash

Conclusion

The Collaboratory has made significant progress in the energy research sector by ensuring cost-effective and efficient solutions that emphasize coordination among diverse, experienced individuals to optimize results. The Collaboratory anticipates sustained growth in this sector, not only within North Carolina but nationwide, as the US progresses towards a low-carbon economy.

The rising frequency of natural disasters, such as Hurricane Helene, underscores the urgent need for further research into mitigation, resilience, and management strategies. The Collaboratory is actively addressing these challenges through its clean energy research initiatives, which it plans to expand in the coming years.

North Carolina is at the forefront of innovation, possessing the intellectual, economic, and natural resources needed to lead the energy transition. The expectation is that the work and research carried out over the next several years as part of the Collaboratory's next-generation energy portfolio will catalyze industry projects, support new technological innovation and provide current analysis to NC leaders as they continue to chart a course for our State's energy sector.

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Acknowledgments

The North Carolina Collaboratory is a funding agency that partners with academic institutions and state agencies to transform research into practical information for use by State and local government. Initially focused on natural resources and environmental issues, the Collaboratory has since broadened its portfolio to include research on some of the State's most pressing challenges, including within the public health, education, clean energy, economic recovery, and technology sectors.

Since its authorization in 2016 by the North Carolina General Assembly the Collaboratory has stewarded $225 million in appropriations from the legislature, investing in over 600 research projects across all 17 University of North Carolina System campuses and numerous NC-based private colleges and universities. The Collaboratory is committed to developing innovative, evidence-based solutions that serve the State and its constituents.

More information about the Collaboratory can be found at collaboratory.unc.edu

The NC Collaboratory proudly acknowledges the parternships that made this research possible through collaboration with industry, government, and academic institutions.

Additionally, The NC Collaboratory thanks the undergraduate interns who worked to make this report possible: **Victoria Farella**, **Carlisle Shore**, and **Chloe Williamson**.

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