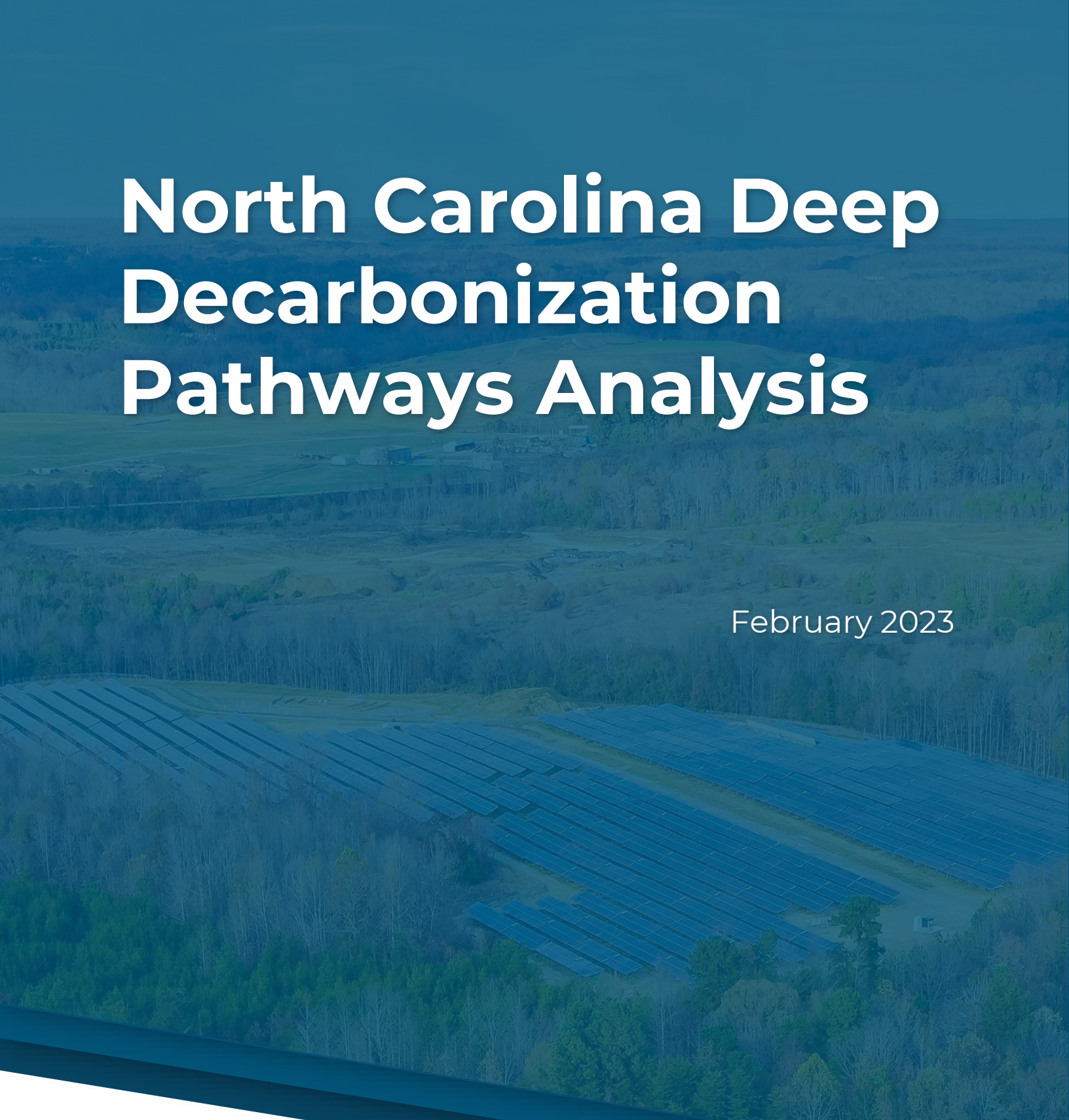
# North Carolina Deep Decarbonization Pathways Analysis



February 2023

Office of
Governor Roy Cooper

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This project was completed with support from the U.S. Climate Alliance.

## Figures

# Tables

# Glossary of Terms

| Acronym | Definition |
|---|---|
| 2022 Inventory | 2022 North Carolina Greenhouse Gas Inventory |
| ACEEE | American Council for an Energy-Efficient Economy |
| ACT | Advanced Clean Trucks program |
| AIM Act | American Innovation and Manufacturing Act |
| BEV | battery electric vehicle |
| BIL | Bipartisan Infrastructure Law signed by President Biden in November 2021 |
| Blueprint | North Carolina's first statewide Flood Resiliency Blueprint developed by North Carolina Department of Environmental Quality's Division of Mitigation Services |
| BOEM | Federal Bureau of Ocean Energy Management |
| CAFE | Federal Corporate Average Fuel Economy |
| CBO | Congressional Budget Office |
| CCS | $CO_2$ capture and storage |
| CEP | North Carolina Clean Energy Plan |
| CEYA | North Carolina's Clean Energy Youth Apprenticeship program |
| Climate Council | North Carolina Climate Change Interagency Council |
| $CO_2e$ | carbon dioxide equivalent that represents the number of metric tons of $CO_2$ emissions with the same global warming potential as one metric ton of another greenhouse gas |
| COP21 | 2015 United Nations Climate Change 21st Conference of Parties in Paris, France |
| DAC | direct air capture of $CO_2$ |
| DAQ | North Carolina Division of Air Quality |
| DHHS | North Carolina Department of Health and Human Services |
| E3 | Energy and Environmental Economics, Inc. |
| EDA | U.S. Department of Commerce's Economic Development Administration |
| EJEAB | Environmental Justice and Equity Advisory Board |
| EO | Executive Order |
| EPA | U.S. Environmental Protection Agency |
| ESI | Environmental Stewardship Initiative |
| GESC | Guaranteed Energy Savings Contract |
| GHG | greenhouse gas |
| HERO | High Efficiency Residential Option Code |
| HFC | hydrofluorocarbon |
| HFCV | hydrogen fuel-cell vehicle |

| Acronym | Definition |
|---|---|
| IEA | International Energy Agency |
| IECC | International Energy Conservation Code |
| IRA | Inflation Reduction Act of 2022 signed by President Biden in August 2022 |
| IWG | Federal Interagency Working Group on the Social Cost of Carbon |
| LDV | light-duty vehicle |
| LEAD | North Carolina Department of Commerce's Labor and Economic Analysis Division |
| LULUCF | land-use, land-use change, and forestry |
| MHD | medium- and heavy-duty |
| MHD ZEV MOU | Multi-state Medium- and Heavy-Duty Zero-Emission Vehicles Memorandum of Understanding |
| MMT | million metric tons |
| MOVES | U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator |
| MSW | municipal solid waste |
| NC A&T | North Carolina Agricultural and Technical State University |
| NC TOWERS | North Carolina Taskforce for Offshore Wind Economic Resource Strategies |
| NCBCC | North Carolina Building Code Council |
| NCCTP | North Carolina Clean Transportation Plan |
| NCDEQ | North Carolina Department of Environmental Quality |
| NCDOA | North Carolina Department of Administration |
| NCDOT | North Carolina Department of Transportation |
| NCORR | North Carolina Office of Recovery and Resiliency |
| NCSR | North Carolina Science Report |
| NET | negative emissions technology |
| NEVI | National Electric Vehicle Infrastructure Program |
| NREL | National Renewable Energy Laboratories |
| NWL | natural and working lands |
| Pathways Analysis | Deep Decarbonization Pathways Analysis |
| PFC | perfluorochemical |
| PHEV | plug-in hybrid electric vehicle |
| RCCP | North Carolina Department of Environmental Quality's Resilient Coastal Communities Program |
| Resilience Plan | North Carolina Climate Risk Assessment and Resiliency Plan |
| RISE | North Carolina Office of Recovery and Resiliency's Regions Innovating for Strong Economies & Environment program |
| SC-GHG | social cost of greenhouse gas emissions |

| Acronym | Definition |
|---|---|
| SLCP | short-lived climate pollutant |
| SMART-POWER | Southeast and Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources |
| STEM | science, technology, engineering, and math |
| TAG | Technical Advisory Group for the North Carolina Pathways Analysis |
| The Commission | North Carolina Utilities Commission |
| TRL | technology readiness level |
| UN | United Nations |
| USI | Utility Savings Initiative |
| VMT | vehicle miles travelled |
| VW | Volkswagen |
| WAP | Weatherization Assistance Program |
| ZEV | zero-emission vehicle |

# Introductory Letter from Governor Cooper

STATE OF NORTH CAROLINA
OFFICE OF THE GOVERNOR

ROY COOPER
GOVERNOR

In North Carolina, the work to fight climate change and grow our economy goes hand in hand. North Carolinians are no strangers to the impacts of a changing climate as the state grapples with more frequent and severe hurricanes and flooding events. Many sources of planet-warming greenhouse gases also emit local pollution that disproportionately harms low-income communities, communities of color, and other underserved populations. At the same time, we've enjoyed major job growth and economic expansion in the clean energy industry. In just the past year, North Carolina has celebrated some of the largest economic development and job growth announcements in the state's history, all driven by the global market transition to clean energy technology.

Since issuing Executive Order No. 80 in 2018, my Administration has taken decisive action to confront the climate crisis and develop our clean energy economy. We've convened hundreds of community members, industry leaders, elected officials, technical experts, and other diverse stakeholders to develop and execute a shared vision for a clean energy transition that is reliable, affordable, and equitable while creating opportunities for all North Carolinians. We worked with a bipartisan coalition to pass a bill that will reduce carbon emissions in the power sector 70% by 2030 and achieve carbon neutrality by 2050. I've issued numerous executive orders promoting the growth of the offshore wind industry, zero-emission vehicles, and our clean energy workforce. Our work is paying off. Current policies put North Carolina on track to reduce overall greenhouse gases 46% by 2030 and 60% by 2050, and our state is ranked in the top 10 of the nation for clean energy jobs and first for rural clean energy jobs.

We're making progress but there is more work to do. I called for this Deep Decarbonization Pathways Analysis in Executive Order No. 246 to help identify the most promising opportunities to further reduce emissions in the near- and mid-term and highlight long-term needs for development and commercialization of emerging technologies. These insights will inform our work ahead-- including investing unprecedented federal resources in clean energy, implementing the state's Carbon Plan under House Bill 951, and finalizing the North Carolina Clean Transportation Plan pursuant to EO 246. State government cannot do this work alone. This report's key findings and recommendations are also designed to inform ongoing contributions from the public, private, academic and advocacy sectors.

I want to conclude by expressing my appreciation for the members of the public, including our Technical Advisory Group, who shared their perspectives and expertise throughout the development of the Pathways Analysis. I also want to thank the many state employees across several Cabinet Agencies who contributed to this effort. North Carolina will continue to lead the way in this decisive decade for climate action thanks to your expertise, perspective, and tireless engagement. We look forward to the important work ahead.

Sincerely,

Roy Cooper

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# Executive Summary

## *Background*

The Cooper Administration has prioritized bold action to confront the climate crisis and grow North Carolina's clean energy economy in a manner that centers equity and affordability and creates opportunities for all North Carolinians (see Climate and Clean Energy Progress section starting on page 23 for more detail). The Administration has issued numerous executive orders to establish science-based greenhouse gas (GHG) targets, mobilized a whole-of-government approach to achieve those targets, and convened diverse stakeholders in planning and implementation efforts.

EO 246 directed the development of this Deep Decarbonization Pathways Analysis (Pathways Analysis) to help the state achieve its climate goals. While North Carolina has significantly reduced GHG emissions, even as the state's population and economy have grown, more action is needed to achieve the science-based GHG goals established in EO 80 and EO 246. By modeling illustrative, forward-looking pathways to achieve emissions targets, this analysis is designed to help policymakers and stakeholders understand the biggest opportunities to reduce emissions and sequester carbon as well as explore the tradeoffs between different emission-reduction strategies.

Executive Order No. 80 (EO 80), issued in 2018, established a goal for North Carolina to *reduce GHGs at least 40% below 2005 levels by 2025*. In 2022, Executive Order No. 246 (EO 246) established new GHG goals for the state to *reduce emissions to at least 50% below 2005 levels by 2030 and achieve net zero emissions no later than 2050.*

### The Goals of this Pathways Analysis Include:

- Analyzing technologically feasible GHG emission reduction pathways consistent with the State's climate goals, including sector-specific emissions (e.g., electricity, transportation) and carbon sequestration trends over time.
- Identifying key policy and planning takeaways, drawing from individual pathways and a comparison between pathways to inform near-, mid-, and long-term decarbonization efforts.
- Equipping policymakers and stakeholders with a better understanding of how to achieve deep decarbonization goals both across the economy and within specific sectors, building on existing statewide efforts.

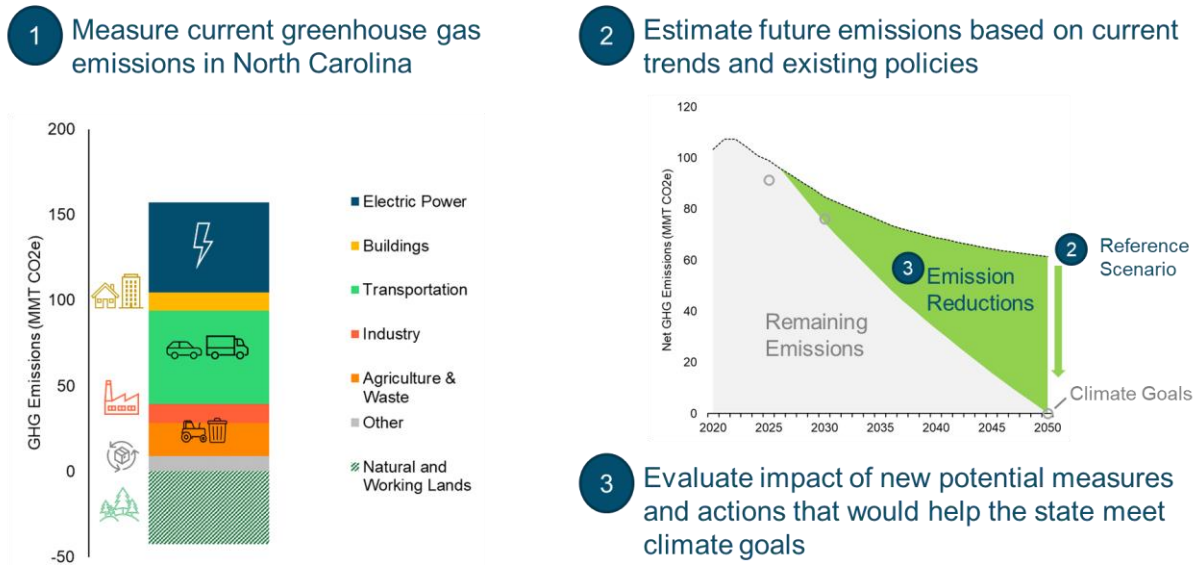
## *Modeling Approach*

To complete the analysis, the Governor's Office and an Interagency Steering Committee worked with consulting firm Energy and Environmental Economics (E3), a Technical Advisory Group, and numerous other stakeholders to develop an analytical model of all sources of GHG sources and sinks in North Carolina. This modeling approach, referred to as "PATHWAYS", was conducted in three core steps as illustrated in Figure 1:

1. Measuring the current state of emissions based on the 2022 North Carolina GHG Inventory (*2022 Inventory*)

2. Estimating future emissions based on current trends and existing polices through the modeling of the Reference Scenario
3. Evaluating the impact of new potential measures and actions that would help the state meet climate goals through the modeling of multiple Net-Zero Scenarios

***Figure 1.*** *Key Steps of the PATHWAYS Analysis*



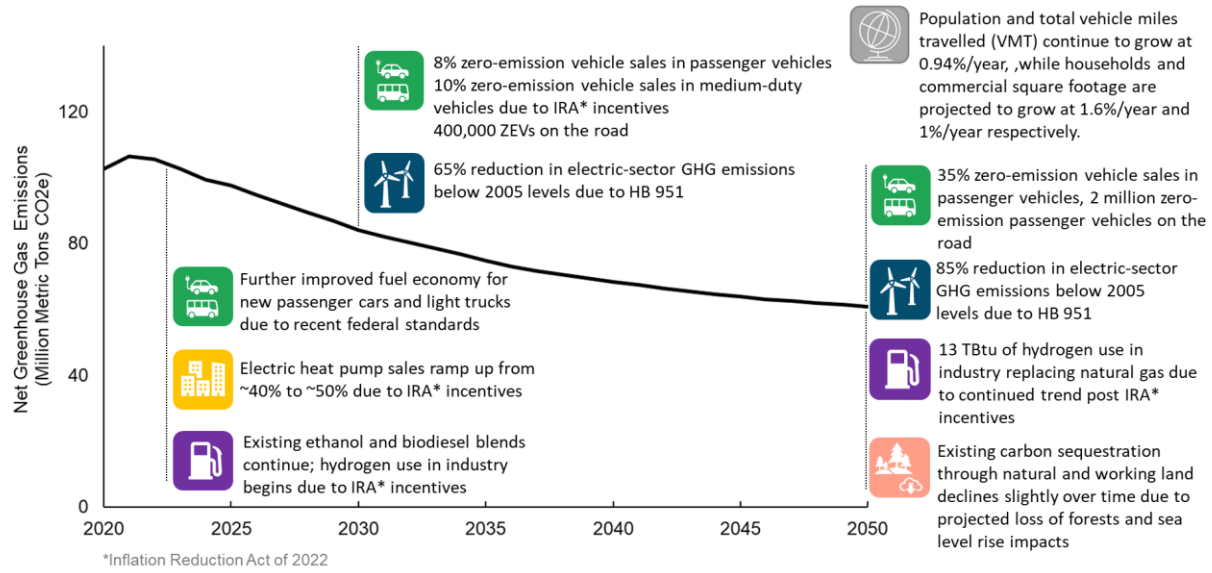

Current GHG emissions in North Carolina[1] are dominated by transportation (mainly passenger vehicles) and direct emissions from electricity generation, though all categories of emissions are critical to monitor and decarbonize to meet the State's ambitious climate goals (Figure 2).

[1] North Carolina's current emissions profile, as shown in Figure 2, is based on the latest 2022 NC State GHG Inventory. All GHG emissions associated with consumption of electricity in buildings, industry, and transport are accounted for in the "Electric Generation" category

***Figure 2.*** *Current North Carolina Gross GHG Emissions by Subsector, Based on 2022 NC GHG Inventory*


The Reference Scenario reflects key technology trends and policies in North Carolina such as population growth and customer investments in zero-emission vehicles (ZEVs) and efficient household appliances from the Inflation Reduction Act (IRA) as shown in **Figure 3**. It achieves 37% reductions in GHG emissions by 2025, 46% reductions by 2030, and 60% reductions by 2050 relative to 2005 levels. The Reference Scenario is an important starting point to understanding North Carolina's current emissions path-- it demonstrates that even though North Carolina is on track to reduce emissions over time, more action is needed to achieve the State's climate targets.

***Figure 3.*** *Key Measures in the Reference Scenario*




After measuring current GHG emissions in North Carolina and developing the Reference Scenario based on current trends and existing policies, the project team developed three Net-Zero Scenarios (see **Figure 4**). These scenarios explore various approaches to achieving net-zero GHG emissions in North Carolina by 2050:

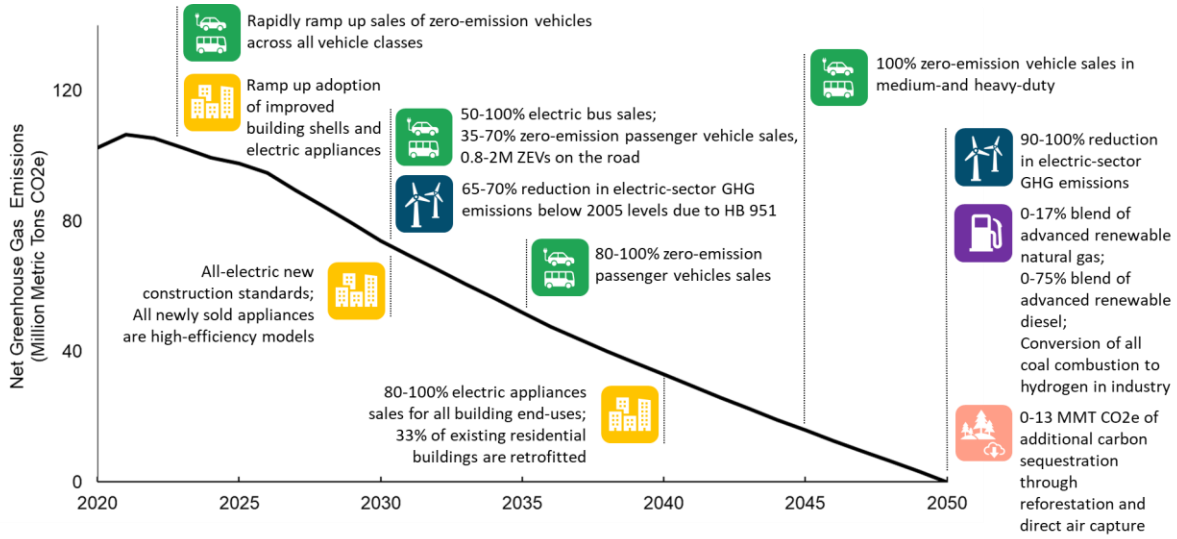
- **High Electrification Scenario** testing higher levels of electrification in buildings, transportation, and industry to achieve the state's decarbonization targets;
- **High Decarbonized Fuels Scenario** testing a larger role for advanced decarbonized fuels, such as advanced biofuels[2] and green hydrogen[3], to supplement moderate levels of electrification; and
- **High Carbon Storage Scenario** exploring what volume of carbon offsets would be needed to achieve net zero either from lands and forests or through negative emissions technologies (NETs)[4] under moderate levels of electrification and without relying on decarbonized fuels.

[2] Advanced biofuels in this scenario are only produced using biomass wastes and residues from existing economic activities (e.g., methane from existing landfills, leftover residues from agricultural yields, etc.) based on the feedstock potential identified in North Carolina through the Department of Energy Billion Ton Report: https://www.energy.gov/eere/bioenergy/2016-billion-ton-report. Purpose-grown biomass produced specifically for use as energy crops were excluded due to concerns around sustainability and potential conflicts with land use for agriculture and other economic activities.

[3] Green hydrogen is produced through electrolysis powered by renewable electricity. This can be compared to other methods of hydrogen production such as gray hydrogen (produced through steam methane reforming [SMR] of natural gas) or blue hydrogen (SMR with carbon capture).

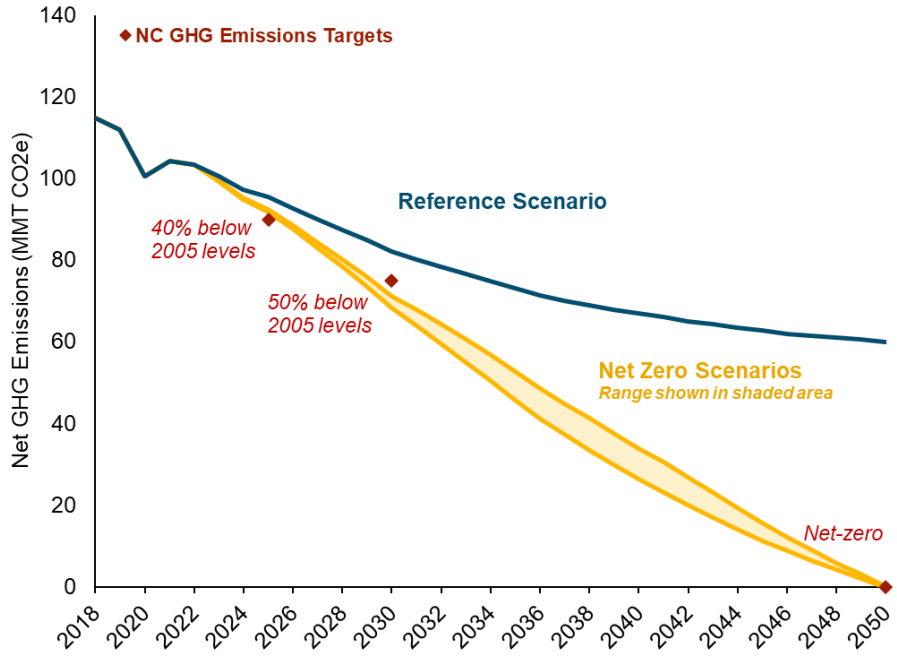
[4] NETs include any technology that produces negative GHG emissions. Commonly modeled NETs are DACs or sustainably grown bioenergy with CCS (BECCS).

***Figure 4.*** *North Carolina Greenhouse Gas Emissions Reduction Measures: Net-Zero Scenario Ranges*



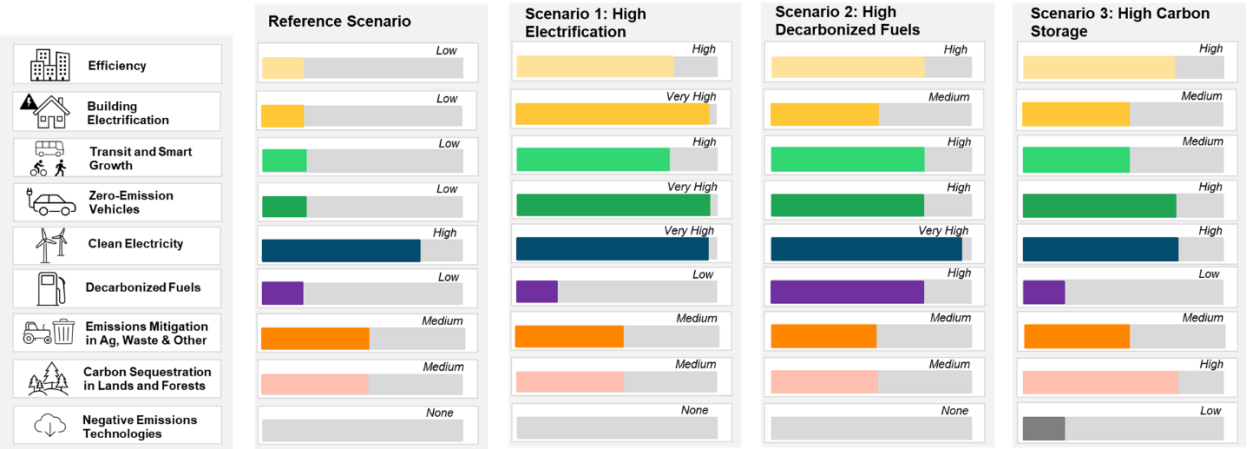

All three Net-Zero Scenarios achieve net-zero GHG emissions by 2050 (Figure 5), though each scenario relies on a different mix of mitigation technologies and intensity of implementation. In addition, all the scenarios are within 1% of the 2025 GHG target of a 40% reduction below 2005 levels, and they all overachieve the 2030 target of a 50% reduction on their path to 2050.

***Figure 5.*** *Net Greenhouse Gas Emissions by Scenario*



The objective of the Pathways Analysis is not to choose a specific pathway. Rather, the variances between pathways are designed to help policymakers and stakeholders understand the biggest opportunities to reduce emissions and sequester carbon as well as explore tradeoffs between different emission-reduction strategies. The key differences across the scenarios (see Figure 6) are the pace of electrification of buildings and vehicles, the level of clean electricity, and the use of advanced biofuels and additional carbon sequestration to help achieve net zero by 2050.

***Figure 6.*** *Net-Zero Scenario Design: Level of Transformation by Measure*




## *Key Findings and North Carolina's Roadmap to Net Zero*

The results show that, regardless of the different mix of mitigation technologies each pathway relies on, there are commonalities across all scenarios to help meet North Carolina's climate targets. These commonalities represent near-term opportunities for "no-regret" actions, as summarized in the seven Key Findings:

1. **Accelerate a transition to ZEVs and electric heat pumps** in buildings as electricity becomes the foremost fuel powering the economy. In 2050, electricity meets 57-67% of all energy demand-- up from about 30% today.
2. **Rapidly decarbonize electricity generation** by scaling up renewable electricity sources and battery storage as the emissions intensity of North Carolina's electricity generation decreases by 93-100% by 2050 to achieve net-zero goals.
3. **Encourage high levels of energy efficiency**, such as adoption of efficient appliances and vehicles, improvement of building shells, and reduction in vehicle miles traveled. Efficiency measures allow energy use per capita to decrease by approximately 45% by 2050 while meeting the same services.
4. **Support commercialization of decarbonized fuels**, at a minimum, to green hydrogen for industry and large trucks and explore pilots for advanced biofuels using sustainable biomass feedstocks. Decarbonized fuels serve a critical but targeted role for hard-to-electrify sectors, accounting for 3-13% of energy demand by 2050.

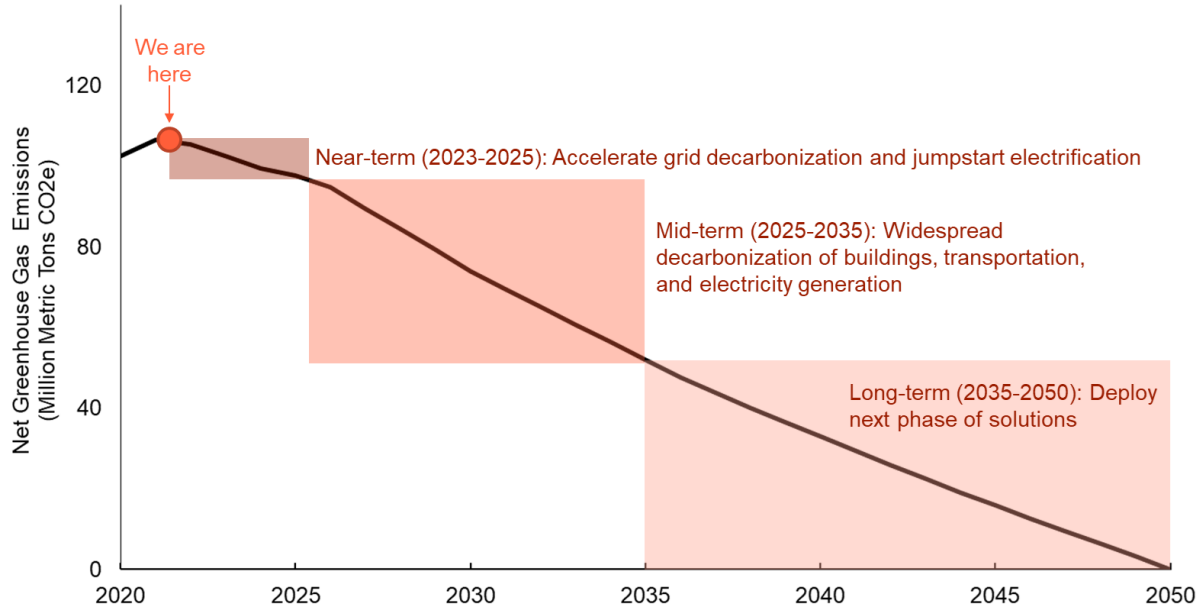
5. **Reduce non-energy GHG emissions** from industry, agriculture, waste, and oil and gas systems as the non-energy sectors can achieve 12% reductions in 2050 compared to the Reference Scenario trajectory with existing policy and trends.
6. **Prioritize sustainable management of natural and working lands** to enhance the critical role of carbon sequestration in helping achieve net-zero emissions. The potential of enhancing natural carbon sinks through land conservation, land management, and forest restoration, when combined with direct air capture of $CO_2$ (DAC), can lead to an additional 10 million metric tons (MMT) of annual sequestration in 2050.
7. **Reduce fuel combustion while decarbonizing the economy** to create co-benefits for air quality improvement, especially in disadvantaged communities. Compared to today, fossil fuel combustion is reduced 50-100% across all net-zero scenarios by 2050.

***Roadmap to Net Zero:***

The PATHWAYS Analysis highlights the critical need and opportunity to transform every sector of the economy on a path to net-zero GHG emissions by 2050. Success will require sustained, equitable and ambitious action. While there is no single path to reach the State's climate goals, all transitions to a net-zero future share the "no-regret" Key Findings outlined above. Drawing from those commonalities, the report outlines North Carolina's Roadmap to Net Zero (Roadmap) outlining more targeted recommendations and identifying timely opportunities for the state to reduce emissions. The Roadmap separates recommendations into three phases (shown in **Figure 7**):

1. Near-term actions that should be prioritized in the next few years;
2. Mid-term actions that should be ramped up before 2035; and
3. Long-term actions that will be needed to achieve 2050 goals.

***Figure 7.*** *Three Phases of North Carolina's Roadmap to Net Zero*



Near-term actions over the next three years should lay a solid foundation for the midcentury transition to clean electricity and widespread electrification, including:

- **Accelerating electric grid decarbonization** via the implementation of the Carbon Plan.[5]
- **Jumpstarting electrification for light-, medium-** and **heavy-duty vehicles** and **enhancing the efficiency of the transportation system** through implementation of the North Carolina Clean Transportation Plan, **Executive Order 271 (EO 271)** and the investment of unprecedented federal funding.
- **Electrifying low-cost building space heating and water heating applications** while **maximizing energy efficiency in buildings** through the investment of federal electrification and weatherization funding and the work of the North Carolina Building Code Council (NCBCC).
- **Exploring additional opportunities for carbon storage and sequestration in North Carolina's natural and working lands** as part of the efforts to implement the 2020 North Carolina Natural and Working Lands Action Plan.
- **Building on PATHWAYS findings to ensure steady progress towards an affordable, equitable, and reliable net-zero future.** Conducting further analysis and engagement around environmental justice and economic impacts while developing a plan for monitoring progress toward climate targets and infrastructure deployments.

Mid-term actions need to help North Carolina achieve widespread decarbonization of electricity generation, transportation, and buildings from 2025-2035, to hit the state's 2030 goals and be on the right track for 2050 goals, including:

- **Electricity decarbonization** surpassing 70% reduction in $CO_2$ emissions by 2030 on a path to full carbon neutrality by 2050, building upon **House Bill 951** requirements with additional consideration for decarbonizing all electricity generation consumed in the State.
- **Transportation decarbonization** to replace most older vehicles with cleaner alternatives when they come off the road, supported by the buildout of a robust charging and fueling infrastructure network for zero-emission vehicles.
- **Building decarbonization** focusing on space heating and water heating via (1) updates of codes and standards, (2) deployment of more efficient and electric appliances in existing buildings, and (3) integrated electric system planning that may include a role for hybrid heating systems for existing buildings.
- **Prioritizing solutions for short-lived climate pollutants**, including methane and hydrofluorocarbons (HFCs), **and researching new technologies that have not yet reached commercial maturity**, including decarbonized fuels such as green hydrogen or advanced biofuels; negative emissions technologies such as DAC; and innovation in agriculture, waste, and industrial processes.

[5] On December 30, 2022, the NCUC issued an order adopting the state's first Carbon Plan, which is targeted to achieve House Bill 951's required carbon emission reductions.

Long-term actions need to prioritize deployment of the next phase of solutions[6] after 2035, tackling some of the more challenging applications such as industry, agriculture, waste, and off-road transport applications. Additionally:

- **Research and development** will need to continue in the 2020s and 2030s to ensure that solutions can be deployed at scale to reach 2050 goals. In particular, additional support will be needed to commercialize advanced biofuels, green hydrogen, ZEVs for all vehicle classes, industrial electrification, and DAC.
- North Carolina should ramp up efforts to increase **carbon storage and sequestration** from natural and working lands, building upon stakeholder recommendations in the 2020 North Carolina Natural and Working Lands Action Plan.

[6] All decarbonization pathways scenarios include technologies that are at least at pre-commercial demonstration phase to ensure that we do not rely on technologies that are too nascent, but additional research, development, and deployment will be needed to commercialize a full portfolio of options.

# Background

## North Carolina's Climate and Clean Energy Goals

### Executive Orders

The Cooper Administration has prioritized bold action to confront the climate crisis and grow North Carolina's clean energy economy in a manner that centers equity and affordability and creates opportunities for all North Carolinians. Starting in 2018, the Administration has issued numerous executive orders to establish science-based greenhouse gas (GHG) targets, mobilize a whole-of-government approach to achieve those targets, and convene diverse stakeholders in planning and implementation efforts.

In October of 2018, Governor Cooper issued Executive Order No. 80 (EO 80) calling for the State of North Carolina to reduce pollution and protect its environment while growing the clean energy economy. The order laid out a series of goals for the state to accomplish by 2025, including:

- Reducing statewide GHG emissions to 40% below 2005 levels;
- Increasing the number of registered, zero-emission vehicles (ZEVs) to at least 80,000; and
- Reducing energy consumption per square foot in State-owned buildings by at least 40% from Fiscal Year 2022-2023 levels.

EO 80 also created the North Carolina Climate Change Interagency Council and directed complementary actions to help achieve the Order's goals.

Governor Cooper affirmed and strengthened North Carolina's commitment to climate action and growing the clean energy economy by signing **Executive Order No. 246** (EO 246) in January of 2022. EO 246 updated North Carolina's clean energy and emission-reduction goals and directed numerous actions to achieve those goals in a manner that centers environmental justice and maximizes health and economic benefits for all North Carolinians.

New goals establish by EO 246 include:

- Reducing statewide GHG emissions to at least 50% below 2005 levels by 2030 and achieving net-zero emissions as soon as possible but no later than 2050; and
- Increasing the total number of registered ZEVs to at least 1,250,000 by 2030 and increasing the sale of ZEVs so that 50% of in-state sales of new passenger vehicles are zero-emission by 2030.

*Executive Order No. 246's Science-Based Greenhouse Gas Targets*

In December of 2015, leaders from around the world met in Paris for the annual United Nations (UN) Climate Change Conference (COP21) under the UN Framework Convention on Climate Change. At COP21, negotiators finalized a historic international treaty (the Paris Agreement) that includes commitments from 194 parties to reduce their emissions, work together to adapt to the impacts of climate change, and strengthen climate commitments over time.

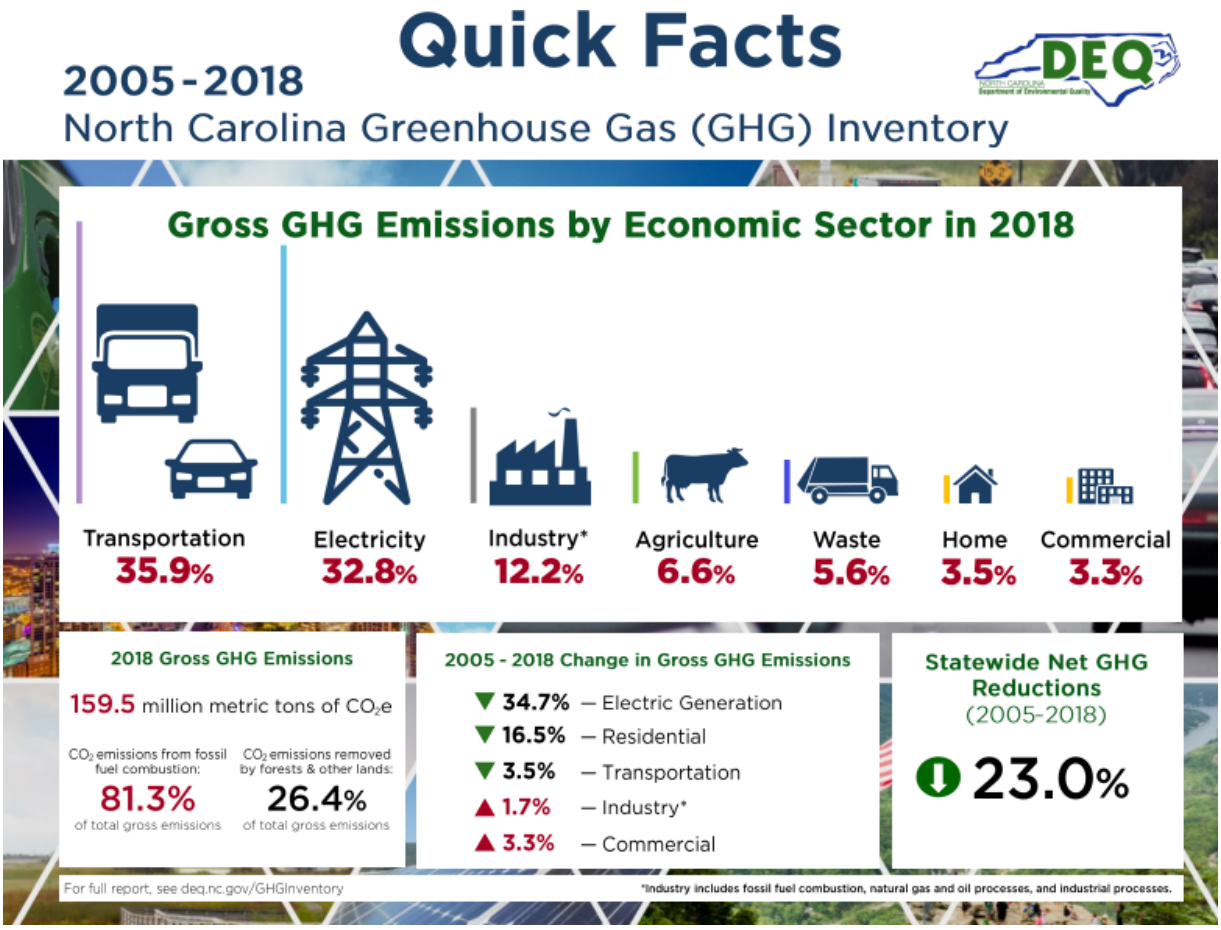
### Climate Progress

EO 246 directed the North Carolina Department of Environmental Quality (NCDEQ) to release an updated *North Carolina Greenhouse Gas Inventory (2022 Inventory)* by January 31, 2022 and biennially thereafter. The inventory's purpose is to provide a high-level perspective of human-caused GHG emissions from various economic sectors in North Carolina.

The *2022 Inventory* includes a detailed accounting of historical activities and associated GHGs emitted or stored by key source categories from 1990 to 2018. The inventory also projects North Carolina's GHG emissions from 2019 to 2030 based on forecasted changes in fuel use, population, historical trends, recently implemented laws and rules, and other factors.

Between 2005 and 2018, NCDEQ estimates that North Carolina reduced gross GHG emissions by 16% and net GHG emissions by 23%. During this same time period, North Carolina's population and real gross state product grew by 19% and 24%, respectively. The *2022 Inventory* projects net GHGs to decrease 30% by 2025 and 39% by 2030, relative to the 2005 baseline.

***Figure 8**. Summary of 2022 North Carolina Greenhouse Gas Inventory*[7]




[7] Source: Greenhouse Gas Inventory | NC DEQ

# Pathways Objectives

## Summary

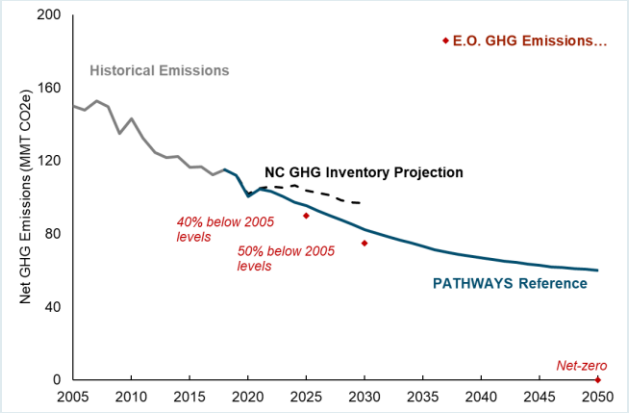
EO 246 directed the development of this Deep Decarbonization Pathways Analysis (Pathways Analysis) to help the State analyze strategies to achieve its climate goals. While North Carolina has significantly reduced GHG emissions, even as the State's population and economy have grown, more action is needed to achieve the GHG goals established in EO 80 and EO 246. By modeling illustrative, forward-looking pathways to achieve emissions targets, this analysis is designed to help policymakers and stakeholders understand the biggest opportunities to reduce emissions and sequester carbon as well as explore the tradeoffs between different emission-reduction strategies.

## The Pathways Goals Include:

- Analyzing technologically feasible GHG emission reduction pathways consistent with the State's climate goals, including sector-specific emissions (e.g., electricity, transportation) and sequestration trends over time.
- Identifying key policy and planning takeaways, drawing from individual pathways and a comparison between pathways, to inform near-, mid-, and long-term decarbonization efforts.
- Equipping policymakers and stakeholders with a better understanding of how to achieve deep decarbonization goals both across the economy and within specific sectors, building on existing statewide efforts.

The modeling in this report builds on the *2022 Inventory*. As discussed in the section "Introduction to Modeling," starting on page 43, this report's emissions projections are aligned with the *2022 Inventory* but also include updated emissions projections that incorporate policies enacted after 2020. Including these more recent updates, the **PATHWAYS modeling shows that North Carolina is on track under current policies to reduce GHGs 37% by 2025, 46% by 2030, and 60% by 2050, relative to the 2005 baseline.**

***Figure 9.*** *Net Greenhouse Gas Emissions Projection from the PATHWAYS Reference Scenario*



# Climate and Clean Energy Progress in North Carolina

## *State Leadership and Ongoing Efforts*

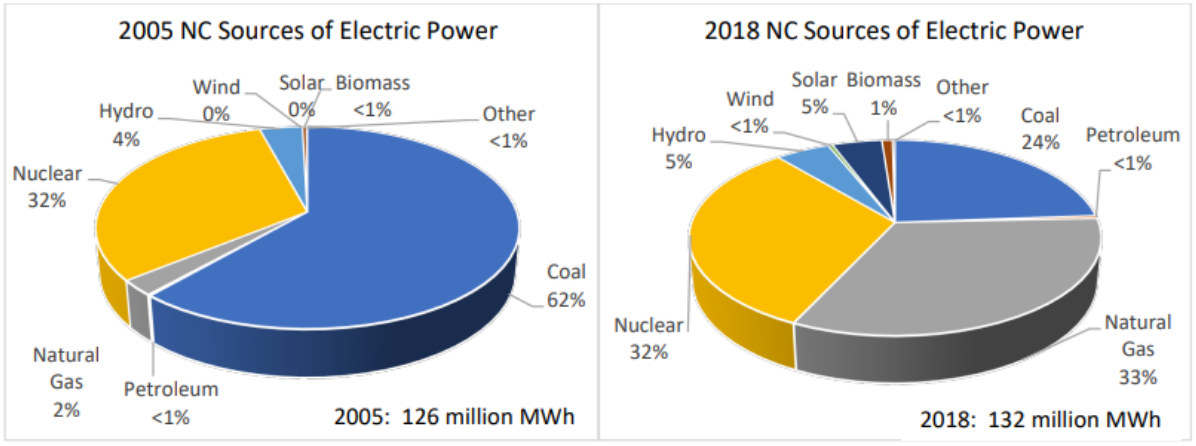
The Cooper Administration's whole-of-government approach to confront climate change and grow the State's clean energy economy spans individual sectors, such as transportation and electricity, as well as cross-cutting initiatives ranging from workforce development to environmental justice. This section reviews some of those initiatives, and the "Roadmap to Net-Zero Section" elaborates on how these ongoing initiatives can contribute to key findings identified in this report.

## *Sector-Specific Initiatives*

### *Electricity*

North Carolina's electricity sector enables the State's quality of life and daily function. Technology advances, policy initiatives, and other efforts have prompted dramatic changes to the State's electricity generation. The decrease in coal generation has reduced GHG emissions by almost 35%, as shown in Figure 10. Governor Cooper has worked with other State leaders to ensure this sector continues its transition to affordable, reliable, and clean sources of energy that benefit all residents and grow the State's economy. The benefits of cleaner electricity can also be extended across the economy in new sectors like transportation (e.g., electric cars) and buildings (e.g., heat pumps).

***Figure 10**. Changes in North Carolina Sources of Electricity Generation, 2005-2018*[8]




### Clean Energy Plan

In addition to establishing the State's first GHG reduction goals, EO 80 also directed NCDEQ to develop a North Carolina Clean Energy Plan (Clean Energy Plan) to examine the utilization of clean energy resources and the integration of those resources into a modern, resilient electric grid. In accordance with EO 80, NCDEQ engaged stakeholders and released the Clean Energy Plan in October 2019.

[8] Source: Figure 2-10 from the Greenhouse Gas Inventory | NCDEQ

Building upon EO 80, the Clean Energy Plan aimed to:

- By 2030, reduce electric power sector GHG emissions by 70% below 2005 levels;
- By 2050, attain carbon neutrality;
- Foster long-term energy affordability and price stability for North Carolina's residents and businesses by modernizing regulatory and planning processes; and
- Accelerate clean energy innovation, development, and deployment to create economic opportunities for both rural and urban areas of the State.

To achieve these goals, the Clean Energy Plan recommended that North Carolina establish an updated regulatory model that better aligns utility incentives with public interest outcomes such as clean energy deployment, resiliency, reliability, affordability, and equity. Recommendations included developing policies to accelerate the retirement of uneconomic coal assets and implementing other market-based policies such as performance-based mechanisms, multiyear rate planning, and decoupling utility revenues from customers' electricity use.

### House Bill 951

In 2021, the North Carolina General Assembly passed and Governor Cooper signed House Bill 951 **(HB 951)**. This legislation adopted numerous decarbonizations policies identified in the Clean Energy Plan process, including requiring the North Carolina Utilities Commission (NCUC) to take all reasonable steps to reduce carbon emissions by 70% below 2005 levels by 2030 and achieve carbon neutrality by 2050, authorizing the use of performance-based regulation, and enabling early coal retirements through the securitization of certain unrecovered costs associated with coal generation.

Consistent with the legislation, the NCUC has opened proceedings to implement these directives. The NCUC's proceeding to adopt a Carbon Plan generated significant stakeholder attention. On December 30, 2022, the NCUC issued an order adopting the State's first Carbon Plan, which is targeted to achieve HB 951's required carbon emission reductions. The NCUC has also adopted rules implementing performance-based regulation, and Duke Energy Carolinas, LLC, and Duke Energy Progress, LLC, have both filed applications for performance-based regulation rate cases. Finally, the NCUC has adopted rules regarding the securitization of coal assets.

### Offshore Wind

North Carolina has extensive potential for offshore wind development. In addition to the clean electricity that this would provide, the North Carolina Department of Commerce has calculated that the offshore wind industry has the potential to generate $100 billion in economic development for the State over the next 15 years. The federal Bureau of Ocean Energy Management (BOEM) has already auctioned three lease areas for offshore wind, one off of Kitty Hawk and two in the Carolina Long Bay off of Wilmington. BOEM has also requested comments on an additional draft wind energy areas off North Carolina's coast.

In October 2020, the governors of North Carolina, Maryland, and Virginia created the Southeast and Mid-Atlantic Regional Transformative Partnership for Offshore Wind Energy Resources (SMART-POWER). The SMART-POWER Memorandum of Understanding provides a framework for the three states to

cooperatively promote, develop, and expand offshore wind energy and the accompanying industry supply chain and workforce.

To maximize the benefit of offshore wind to North Carolina, Governor Cooper signed Executive Order No. 218 (EO 218) on June 9, 2021. EO 218 establishes goals for North Carolina to develop 2.8 gigawatts of offshore wind energy resources by 2030 and 8.0 gigawatts by 2040. The order directs the North Carolina Department of Commerce to name a clean energy economic development coordinator and establish the North Carolina Taskforce for Offshore Wind Economic Resource Strategies (NC TOWERS). The order also directs NCDEQ and the North Carolina Department of Military and Veterans Affairs to designate offshore wind coordinators and take steps to support offshore wind. Finally, the order directs quarterly meetings of the North Carolina Offshore Wind Interagency Workgroup to ensure offshore wind activities are well coordinated among leadership in relevant agencies.

## *Transportation*

North Carolina's transportation system underpins the State's connectivity and economic function. It also greatly impacts the daily health, safety, and well-being of millions of residents and visitors. Governor Cooper has taken swift action to invest in critical infrastructure and support the state's transition to a clean transportation future.

### Executive Order No. 80

EO 80 established the state's first ZEV target with a goal to increase the number of registered ZEVs to at least 80,000 by 2025. Since that time, North Carolina's ZEV market has quickly expanded. As of October 2022, the State has over 51,000 registered ZEVs — a 300% increase since the issuance of EO 80.[9] ZEVs accounted for approximately 1% of light-duty vehicle sales in North Carolina in 2019. By the second quarter of 2022, this number had increased to nearly 5% of light-duty vehicle sales according to the 2022 *Transportation Electrification in the Southeast* report.

EO 80 also called for the North Carolina Department of Transportation (NCDOT) to work with NCDEQ to develop a ZEV plan for the State. NCDOT released the ZEV Plan 1.0 in 2019, highlighting 20 recommendations encompassing the themes of education, convenience, affordability, and policy. In 2022, NCDOT published a ZEV Plan Progress Update providing updates on the recommendations and outlining next steps to further progress towards the State's ZEV adoption targets.

### Executive Order No. 246

EO 246 expanded North Carolina's ambition to build a clean and equitable transportation system. The order expanded EO 80's ZEV adoption goal to 1,250,000 registered ZEVs by 2030. It also called for 50% of new light-duty vehicle sales to be zero emission by 2030. EO 246 also directed NCDOT to work with other cabinet agencies to develop a North Carolina Clean Transportation Plan (NCCTP) that will identify actionable strategies to decarbonize the transportation sector and achieve the goals in EO 80 and EO 246.

[9] Oct 2018: 12,715 ZEVs; October 2022: 51,042

The NCCTP includes consideration of how North Carolina stakeholders can work together to:

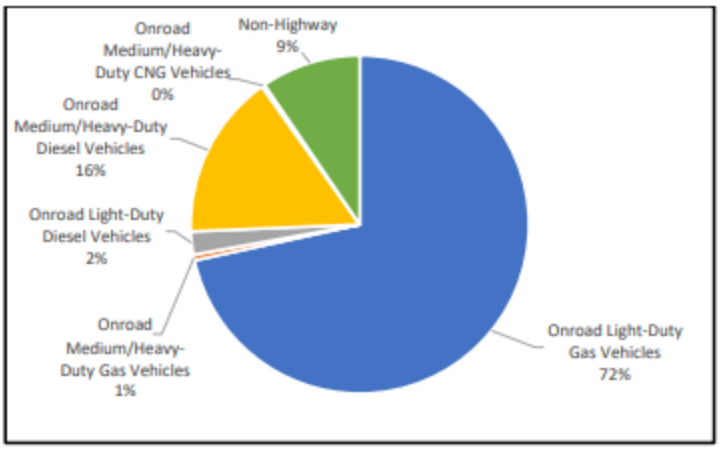
- Increase the availability, sales, and usage of ZEVs
- Reduce vehicle miles traveled
- Invest in clean transportation infrastructure
- Provide equitable access to clean mobility options
- Increase the availability of non-vehicle transportation modes
- Transition to zero- and low-emission fuels

Since EO 246 was signed in January 2022, NCDOT has worked with over 300 stakeholders to assess the opportunities and near-term strategies necessary to create a more equitable clean transportation system. The NCCTP will summarize the State's key action areas and next steps and will be finalized by April 7, 2023.

### Medium- and Heavy-Duty Zero-Emission Vehicles

After passenger cars and trucks, medium- and heavy-duty (MHD) gas and diesel vehicles (i.e., vans, buses, and trucks) are the second largest source of transportation-related GHG emissions. They are also a major contributor to local air pollution.

***Figure 11.*** *Distribution of 2018 North Carolina Transportation Greenhouse Gas Emissions (Source: 2022 GHG Inventory)*[10]




In July 2020, Governor Cooper joined 18 jurisdictions across the U.S. and Canada in signing a multi-state MHD ZEV Memorandum of Understanding (MOU) to reduce pollution and grow the market for zero emission MHD vehicles. The MOU established MHD ZEV sales goals of 30% by 2030 and 100% no later than 2050. Participating jurisdictions, including North Carolina, have engaged stakeholders to develop an Action Plan outlining near-term strategies to achieve the MOU goals for ZEV sales requirements and market incentives. Many of these strategies will be included in the NCCTP

[10] Source: Figure 2-13 from the Greenhouse Gas Inventory | NCDEQ

In October 2022, Governor Cooper issued **Executive Order No. 271 (EO 271),** positioning the State to benefit from the global market transition to zero-emission MHD vehicles by ensuring that new vehicle technologies will be available to businesses across the State and directing State agencies to pursue strategies and investments that will support the affordable, equitable, and reliable growth of the MHD ZEV market. **EO 271** directs NCDEQ to work with stakeholders to propose an Advanced Clean Trucks (ACT) program that would ensure zero-emission trucks and buses are available for purchase in the State. The order also outlines a comprehensive strategy for the State to support automakers, fleet owners, and other partners in growing the MHD ZEV market through investments in charging infrastructure, purchase incentives, workforce development, demonstration projects, technical assistance, and other strategies identified through the NCCTP.

### Volkswagen Settlement

As a result of the Volkswagen (VW) Settlement, an agreement between the German automaker and the U.S. Department of Justice, North Carolina received $98 million to reduce nitrogen oxide emissions from the transportation sector and improve air quality. Governor Cooper designated NCDEQ to manage North Carolina's VW Settlement Program. NCDEQ organized investment efforts into two phases to help improve upon the program over time and incorporate feedback. NCDEQ also allocated the maximum amount allowed under the settlement (approximately $10.2 million) to the Zero Emission Vehicle Infrastructure Program to increase the State's charging capacity.

The Phase 1 VW Program awarded ~$31 million to replace 172 vehicles with cleaner models and to invest in 105 electric vehicle charging stations.

The Phase 2 VW Program awards are still being announced and will collectively include the remaining $66.5 million in available funding. Based on public feedback, Phase 2 prioritizes electric vehicle replacement projects to maximize emission reductions and public health benefits. The Phase 2 VW Program also seeks to invest a significant portion of funding into projects that will benefit underserved communities through scoring bonuses and by assisting under-resourced communities that may not have applied for grants in Phase 1.

Phase 2 award highlights include:

- In August 2022, NCDEQ announced funding to replace 61 transit buses with cleaner vehicles that will significantly reduce GHGs and other harmful air pollutants. A majority of the $13.5 million in available funding was awarded to 25 all-electric buses and associated charging infrastructure. Of the funded buses, 23 are located in historically under-resourced counties to which NCDEQ provided additional outreach and support.
- In October 2022, NCDEQ announced that more than $30.1 million would go toward purchasing 161 new school buses across the State, with the majority of funding going toward new all-electric school buses. Most of the buses (130) were requested in rural counties. Of those, 80 school buses were awarded to schools in the 37 historically under-resourced counties that NCDEQ targeted for additional outreach and support during the application process.

## *Commercial and Residential Buildings*

### Weatherization Assistance Program

The Weatherization Assistance Program (WAP) is a federally funded energy efficiency program for low-to-moderate-income households with a high energy burden. Administered by NCDEQ, the program is designed to:

- Improve energy efficiency
- Reduce energy consumption and costs
- Protect and improve the health and safety of the home occupants
- Increase the value of the housing stock

In Fiscal Year 2021-2022, the program and its community agency partners weatherized 1,178 homes in North Carolina. Between April 2022 and September 2022, an additional 761 homes received major home repairs, energy efficiency and clean energy upgrades, including funding more than 100 ten-year subscriptions to community solar.

### Energy Efficiency in Public Schools

NCDEQ recently partnered with high-poverty, rural and disadvantaged public schools to improve energy efficiency and energy savings. As part of this initiative, DEQ funded LED lighting or HVAC upgrades at 61 public elementary and middle schools in 12 counties across the State. The projects will save an estimated 2,780 MMBTUs (millions) of energy and more than $86K in avoided energy costs annually.

### North Carolina Building Code Council

The North Carolina Building Code Council (NCBCC) comprises 17 appointed members from various backgrounds and establishes and manages the minimum code standards and other voluntary measures for all residential, commercial, and industrial buildings. NCBCC plays an important role in economic development, consumer protection, and climate action. With strong building codes, communities across the State can:

- Save energy and lower utility bills
- Create jobs and promote economic activity
- Protect the health and safety of residents
- Reduce pollution and GHGs

Low-income communities, communities of color, and other underserved communities are not only disproportionately impacted by climate change but are also disproportionately burdened by high energy costs in inefficient buildings. Buildings typically last from 75 to 100 years (many for even longer) and the building code presents an opportunity to ensure ongoing savings through efficient design, technology use, and construction practices, paying dividends to owners and occupants for years to come. As a changing climate fuels more frequent and damaging extreme weather events, strong building codes can also reduce

damage and save lives by ensuring the construction of more resilient infrastructure. NCBCC is currently considering revisions to the residential and commercial codes that will become effective by January 1, 2025.

## *Energy Efficiency*

### North Carolina Energy Efficiency Roadmap

Energy efficiency is the cheapest option to meet energy demand while reducing GHG emissions. In August 2019 the Duke University Nicholas Institute for Energy, Environment and Sustainability partnered with NCDEQ to develop the North Carolina Energy Efficiency Roadmap identifying opportunities to grow the role and impact of energy efficiency across the State. The Roadmap makes 32 recommendations, grouped into 10 focus areas, to achieve three primary objectives:

1. Align interests to create an energy efficiency conducive climate
2. Increase access for hard-to-reach sectors
3. Develop a uniform standard for tracking/benchmarking energy efficiency costs and benefits

This Roadmap was incorporated into the Clean Energy Plan as an Appendix. Key recommendations from the Roadmap became recommendations in the plan.

## *Natural and Working Lands*

North Carolina's natural and working lands (NWL) are estimated to sequester over one quarter of the State's gross GHG emissions and are essential to communities, economies, and ecosystems. These natural resources not only mitigate the impacts of climate change by removing carbon from the atmosphere but also build adaptive capacity and resilience to climate change-related weather extremes and other impacts.

### Natural and Working Lands Action Plan

Following the establishment of EO 80's GHG and resiliency objectives, NCDEQ finalized the Natural and Working Lands Action Plan (NWL Action Plan) in June of 2020. The purpose of this effort was to identify and advance specific opportunities for North Carolina's NWL to further sequester carbon, build ecosystem and community resilience, provide ecosystem benefits, and enhance the State's economy. The plan prioritizes short-term, cost-effective, and pragmatic solutions as well as highlighting longer-term actions that may require more effort, funding, and agency or legislative support.

Specifically, the plan encompasses:

- Defining stakeholders' shared goals
- Presenting the current state of North Carolina's NWLs
- Quantifying the potential benefits of various actions
- Recommending specific actions that facilitate meeting shared goals
- Identifying implementation pathways, partners, and funding to facilitate taking action
- Discussing roadblocks currently preventing the use of certain action pathways

- Encouraging work on broad policy initiatives that would greatly enhance meeting North Carolina's goals

### NWL Stakeholders Group

To develop the NWL Action Plan, NCDEQ engaged land management experts, non-profit organizations, universities, and federal, state, and local government agencies working in conservation, forestry, agriculture, and coastal and urban planning. Many of the expert stakeholders that participated in the development of the NWL Action Plan are currently working toward implementing recommendations through the NWL Stakeholder Group. This implementation effort is led by the Department of Natural and Cultural Resources and organized through six land sector subcommittees:

- Forestry
- Floodplains and Wetlands
- Pocosins
- Coastal Habitats
- Agriculture
- Urban Lands

## *Cross-Cutting Initiatives*

## *Environmental Justice*

Although North Carolina is the birthplace of the environmental justice movement and has a rich history of community advocacy, more work is needed to advance environmental justice within the State. Governor Cooper has taken a whole-of-government approach to advance environmental justice efforts and help improve the quality of life in North Carolina communities. Communities of color, indigenous communities, and low-income communities in North Carolina are disproportionately impacted by the changing climate and are overburdened by exposure to air pollution and other environmental degradation. Decarbonization presents a great opportunity for North Carolina to advance environmental justice and mitigate the climate crisis, but decarbonization policies must reflect and take into consideration environmental justice priorities, such as air quality, energy burden, and affordability.

### Department of Environmental Quality Secretary's Environmental Justice and Equity Advisory Board

In May 2018, under Governor Cooper's leadership, NCDEQ established the Environmental Justice and Equity Advisory Board (EJEAB) to assist in achieving and maintaining the fair and equal treatment and meaningful involvement of North Carolinians regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. The EJEAB provides advice and recommendations to NCDEQ's Secretary on issues raised by communities, including permitting, exposures to human health and the environment, climate change, community capacity building, equitable distribution of resources, and public engagement. The EJEAB serves a critical role in providing guidance and policy recommendations to advance environmental justice.

### Executive Order No. 143

In June 2020, Governor Cooper issued **Executive Order No. 143** (EO 143) establishing the Andrea Harris Task Force to address the disproportionate impact of COVID-19 on communities of color. The mission of the order was to create economic stability, eliminate health disparities, and achieve environmental justice by identifying best practices and developing recommendations for the Governor to address social, economic, environmental, and health areas of concern. Specifically, regarding environmental justice, the order directed focus on enhancing and increasing public participation in low-income and minority communities in agency decisions, quantifying health and welfare benefits of pollution reduction, and advancing climate justice.

The order intends to achieve these improvements by prioritizing actions that equitably reduce GHG emissions, increase community resiliency, and prioritize infrastructure recovery efforts for low-income, minority, and vulnerable communities. The Task Force provided several recommendations addressing environmental justice and equity issues that helped shape EO 246's approach to advance environmental justice (outlined in the next section). These recommendations continue to influence the on-going work of EO 246.

In August 2022, the Andrea Harris Task Force was reestablished by **Executive Order No. 268** (EO 268), with the mission of advising the State government on actions to further economic development in disadvantaged communities, improve health and wellness outcomes in underserved communities, and advance equitable practices within State agencies.

### Executive Order No. 246

EO 246 includes multiple provisions underscoring the importance of environmental justice and equity in the State's transition to a clean energy economy. The order directed cabinet agencies to incorporate environmental justice considerations into the implementation of climate and clean energy efforts and prioritize environmental justice priorities in budget decision-making. Cabinet agencies also developed public participation plans to improve meaningful engagement in agency decision-making with underserved communities and appointed agency environmental justice leads. Lastly, the order directed to the Governor's Office and Cabinet agency leadership to engage advocates and stakeholders to identify additional executive actions to advance environmental justice. These efforts are ongoing.

### Water and Wastewater Project Funding

In July 2022, Governor Cooper and State legislators announced a record $789.4 million in water and wastewater infrastructure funding to help increase community resiliency, improve access to clean water in underserved communities, and support economic growth. This funding was made possible through the American Rescue Plan Act and the 2022-2023 state budget. Several of these funding projects were specifically awarded to underserved or disadvantaged communities to provide access to clean, safe water and replace aging water and wastewater infrastructure in communities that need it most. NCDEQ updated the funding scoring criteria to include Environmental Justice concerns and ensure equitable distribution of available funding. The agency also created a specific category of at-risk funding to address the needs of underserved communities across the State.

### Executive Order No. 271

EO 271 was motivated in part by the desire to advance environmental justice in North Carolina. Air pollution from diesel buses and trucks worsens asthma and other cardio-respiratory illnesses (especially in children and older adults). It can trigger heart attacks and strokes and lead to other negative health impacts. While this pollution harms all North Carolinians, it disproportionately impacts low-income communities and communities of color that are often located near trucking corridors, ports, fleet garages, warehouses, and other distribution hubs. EO 271 provides clear direction for cabinet agencies to prioritize strategies that will further environmental justice and health equity by improving health outcomes for communities disproportionately impacted by air pollution and increasing affordable access to clean transportation options. Under the order, the North Carolina Department of Health and Human Services (DHHS) will also take steps to increase understanding of the disproportionate health impacts of bus and truck emissions on underserved communities and people of color. Some of the DHHS efforts include publishing commentary on the environmental justice impacts of transportation-related air pollutants, incorporating the best available air quality and environmental justice metrics into the DHHS Environmental Health Data Dashboard, and notifying community stakeholders about relevant funding opportunities to address the health impacts of transportation-related emissions.

## *State Government Leading by Example*

The State government plays a major role in transitioning North Carolina to a clean energy economy. Expanding efficiency measures and deploying more clean energy across State government operations saves taxpayer dollars and reduces emissions.

### Utility Savings Initiative

In 2002, North Carolina set a goal for all State agencies and State institutions of higher learning to reduce energy consumption by 30% from their 2002-2003 baseline levels by 2015 (G.S. §143-64.12). EO 80 increased the energy savings goal for all cabinet agencies, requiring a reduction of energy consumption of 40% per square foot by 2025. The North Carolina State Energy Office supports efficiency work through the Utility Savings Initiative (USI), a comprehensive program to manage energy, water, and other utility usage for State agencies. USI provides on-site technical assistance through training, energy audits, and strategic planning guidance. The USI team also oversees the Guaranteed Energy Savings Contract (GESC) process for all government units. GESC is a financing mechanism by which energy efficiency projects can be implemented through realized energy savings within existing utility budgets. USI collects data to track energy usage across all State-owned buildings and submits annual reports to the North Carolina General Assembly and the Office of the Governor.

As of Fiscal Year 2021-2022, State-owned buildings have reduced energy usage intensity 32% below the 2002-2003 baseline while increasing gross square footage by 48% over the same time period. Since 2003, efficiency efforts have saved State-owned buildings more than $1.75 billion in cumulative utility costs. Energy efficiency improvements have also provided air pollution benefits by avoiding fuel combustion directly at the buildings or indirectly at central electric power stations. Fiscal Year 2021-2022 estimates

show that the program avoided 1,053,366 metric tons of carbon dioxide equivalent ($MTCO_2e$ )[11] in GHG emissions for State governmental units. Cumulatively since Fiscal Year 2002-2003, approximately 9.1 million $MTCO_2e$ of GHGs have been avoided for State governmental units, which is equivalent to annual $CO_2$ emissions from the electricity consumed in 1,773,948 homes or two coal-fired power plants.[12]

### Motor Fleet Transition to Zero-Emission Vehicles

EO 80 established a commitment to transition the State motor fleet to zero-emission technologies. Specifically, the order directed cabinet agencies to prioritize the purchase or lease of ZEVs whenever feasible and to prioritize cost-effective, low-emission alternatives when ZEV use is not feasible.

The North Carolina Department of Administration (NCDOA) oversees the motor fleet's ZEV transition. NCDOA publishes an annual Motor Fleet ZEV Plan to provide updates on the motor fleet composition and progress made on prioritized strategies and initiatives. NCDOA's work, in partnership with cabinet agencies, encompasses a variety of topics ranging from installing adequate charging infrastructure to utilizing telematics data to identify the vehicles most suitable for a ZEV replacement.

The 2022 Motor Fleet ZEV Plan update noted several highlights for the State's motor fleet ZEV transition:

- The State fleet includes 36 zero-emission vehicles, and NCDOA recently made the largest ZEV order in fleet history with 75 Chevy Bolts.
- As of Spring 2022, new funding was approved for NCDOA to deploy 73 electric vehicle charging stations in Parking Deck 75 in Downtown Raleigh.
- NCDOA recently acquired seven new Ford E-Transit cargo vans and six charging stations to transport mail between State government agencies through the Mail Service Center.
- In October of 2022, NCDEQ awarded more than $1 million in VW settlement funds to State agencies to install Level 2 ZEV charging infrastructure. These 103 charging ports will be installed at 25 sites, including state parks, museums, aquariums, government office buildings, universities, and community colleges.
- NCDOA recently ordered 421 Toyota Camry Hybrids. These models average 52 miles per gallon (MPG) and will replace Ford Fusions, which average 23 MPG.

EO 271, issued in Fall 2022, directed cabinet agencies to prioritize MHD vehicles as part of their ongoing efforts to transition motor fleets to ZEVs. To support implementation of this directive, NCDOA is seeking to add MHD ZEVs to the State term contracts for its replacement program and will incorporate relevant updates into the agency's annual Motor Fleet ZEV Plan.

### Social Cost of Greenhouse Gas Emissions

Through EO 246, North Carolina is taking steps to better account for the social benefits of avoiding GHG emissions or the social costs of increasing GHG emissions. Specifically, the Cooper Administration is

[11] $MTCO_{2e}$ is metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential. Carbon dioxide equivalents are commonly expressed as "metric tons of carbon dioxide equivalents ($MTCO_{2e}$)."

[12] See the "2022 Comprehensive Program to Manage Energy, Water, and Other Utility Use for State Agencies and State Institutions of Higher Learning" Appendix B for sources and assumptions used in calculating greenhouse gas amounts.

incorporating the social cost of GHG emissions (SC-GHG) into cabinet agency decision-making. The SC-GHG represents the "monetary value of the net harm to society associated with adding [one metric ton of a] GHG to the atmosphere in a given year."[13] This harm to society includes numerous climate change impacts, including "changes in net agricultural productivity, human health effects, property damage from increased flood risk, natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services."[14]

Governments and other entities use SC-GHG as a straightforward method for factoring the societal cost of GHG emissions. Failure to consider climate change impacts during decision-making ignores the significant harm that GHG emissions cause to current and future generations. As SC-GHG is a monetary value, it also simplifies climate change impacts because it easily can be added to benefit-cost analyses.

Section 6 of EO 246 directs the Governor's Policy Office to issue guidelines for the inclusion of SC-GHG into State agency decision-making. The provision reads in part as follows:

> *Within ninety (90) days of the publication of the IWG's [Interagency Working Group on the Social Cost of Carbon] updated SC-GHG estimates, the Governor's Office shall begin releasing guidelines for including and considering these estimates in specifically identified Cabinet agency decision and actions, which the agencies shall follow within the timeframe provided by the guidelines and consistent with applicable law.*

In 2009, President Obama convened the federal Interagency Working Group on the Social Cost of Carbon (IWG) to establish social costs of carbon estimates in federal decision-making. President Trump disbanded the IWG in 2017, and President Biden reconvened it in 2021. President Biden charged the IWG with updating the SC-GHG estimates, and directed federal agencies to use $51 per metric ton of $CO_2$ emissions ($CO_2e$) as the interim SC-GHG level until the IWG releases updated estimates.[15] In November of 2022, the Biden Administration released a draft of the updated SC-GHG numbers. The new draft, subject to public comment through February 13th, 2023, updated the SC-GHG's central value from $51-per-ton to $190, a nearly four-fold increase.

Upon finalization of the IWG's updated SC-GHG estimates, the Governor's Office will work with cabinet agencies to incorporate those new estimates into agency decision making.

### Environmental Stewardship Initiative

Through the Environmental Stewardship Initiative (ESI), NCDEQ works proactively with companies to go beyond environmental compliance. By looking at how they can become stewards of the environment, companies can realize the people, profit, and planet benefits that come with adopting this mindset.

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[13] IWG Feb 2021 page 3 (A Return to Science: Evidence-Based Estimates of the Benefits of Reducing Climate Pollution | CEA | The White House)

[14] IWG page 3 (A Return to Science: Evidence-Based Estimates of the Benefits of Reducing Climate Pollution | CEA | The White House)

[15] Federal Register :: Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis

From large corporations to nonprofit organizations, ESI is a free, voluntary program open to any entity in North Carolina that wants to go above and beyond the minimum regulatory requirements for their management of waste, air, water, and energy. Companies are increasingly making ambitious sustainability goals, and through ESI, NCDEQ provides no-cost technical assistance, including strategies to reduce water and energy usage, for all members. This voluntary program also provides members with networking and outreach opportunities to learn about innovating solutions and share with one another. Under EO 271, NCDEQ will expand ESI to support and recognize companies and facilities that increase their use of ZEVs in their van, bus, and truck fleets.

In the past 20 years, ESI partners have saved over $95 million and have experienced similarly impressive results in their collective environmental impact. Through strategic changes, they have reduced the amount of waste going to landfills by 4.2 million tons. They have also reduced collective $CO_2e$ by over 32 million metric tons, which is equivalent to the CO2 produced by the energy usage of 3.8 million homes for a year. ESI celebrated its 20th anniversary in 2022.

## *Clean Energy Workforce and Economic Development*

The quickly growing clean energy economy presents enormous economic and job growth opportunities throughout North Carolina. Newer and cleaner technologies, ranging from renewable energy to electric vehicles, are being deployed at scale. The public sector is accelerating industry growth through supportive policies and billions of dollars of investment designed to reduce GHGs and other pollution while cultivating a domestic industry that creates careers with family sustaining wages. With a business-friendly environment, shovel-ready sites, unparalleled quality of life, and diverse culture and communities, North Carolina is a national leader in attracting emerging and innovative industries like the clean energy sector.

Over just the past 12 months, North Carolina has celebrated numerous clean energy economic development announcements. Some examples include:

- September 2022: Wolfspeed, Inc., a leading manufacturer of Silicon Carbide semiconductors, announced that it will create more than 1,800 new jobs in Chatham County by 2030. The company will construct a manufacturing campus to produce Silicon Carbide materials with an investment of approximately $5 billion over the next eight years in Siler City. The company's semiconductor technology is used in a variety of applications, including electric vehicles, renewable energy, and energy storage.
- March 2022: VinFast, the Vietnamese auto manufacturer, is building a new line of electric vehicles and selected North Carolina for its first North American automotive assembly and battery manufacturing plant, creating 7,500 jobs. The company intends to invest up to $2 billion in Phase 1 of its project at the Triangle Innovation Point megasite in Chatham County.
- December 2021: Toyota announced it will build its first North American battery manufacturing plant for electric vehicles at the Greensboro-Randolph megasite in North Carolina, creating at least 1,750 jobs and investing $1.29 billion. The automaker subsequently announced an additional investment of $2.5 billion and an additional 350 jobs.

Investing in the State's workforce is key to realizing the full potential of clean energy technology and building a more prosperous, just, and resilient economy for all North Carolinians. The Cooper Administration – in partnership with private sector leaders, workforce development experts, and other community stakeholders – is taking swift action to cultivate the nation's leading clean energy workforce.

### Clean Energy and Clean Transportation Workforce Assessment

In 2019, the North Carolina Department of Commerce (NCDOC) released the Clean Energy and Clean Transportation in North Carolina: A Workforce Assessment. This report, called for by EO 80, encompassed the following topics to support the growth of good-paying clean energy jobs in the State:

- North Carolina's existing talent pool and future workforce demand
- Employers' current and future workforce skills and training needs
- Educational program offerings, enrollment trends, and work-based learning opportunities
- Gaps and areas for improvement to meet current and future workforce demand
- Actions to help North Carolinians develop required skills and acquire further education

### First in Talent Plan

In 2021, NCDOC released the First in Talent plan, North Carolina's strategic plan for economic development. The four-year plan recognizes that investing in North Carolina's workforce is key to building a more prosperous and resilient economy for all North Carolinians and identifies three key goals critical to the State's economic development strategy:

1. Prepare the workforce for career and entrepreneurial success
2. Prepare businesses for success by growing and attracting a talented workforce
3. Prepare communities to be more competitive in growing and attracting a talented workforce and business

The tight labor market in North Carolina requires NCDOC to widen the pool of talent recruited by companies, which means both hiring more workers with barriers to employment and building support systems in our education and training to help them thrive. Emerging opportunities in clean energy industries provide more job seekers with an entry point into career pathways that pay family-sustaining wages. The First in Talent plan includes strategies and tactics to help business recruit and retain talent and to help job seekers receive the education and training needed to participate in the workforce.

### STEPs4GROWTH and the Clean Energy Youth Apprenticeship Program

In August 2022, Governor Cooper joined U.S. Commerce Secretary Gina Raimondo to announce that the U.S. Department of Commerce's Economic Development Administration (EDA) was awarding a $23.7 million American Rescue Plan Good Jobs Challenge grant to North Carolina Agricultural and Technical State University (NC A&T) to create STEPs4GROWTH. STEPs4GROWTH is a clean energy workforce training program designed to promote equity and economic mobility for historically underserved communities.

STEPs4GROWTH will offer workforce training to high school students, recent high school graduates, and adult learners in four clean energy sectors: energy efficiency, renewable energy, clean vehicles, and grid

and storage. Trainees will start by earning short-term industry recognized credentials with the option to build toward an associate degree and ultimately a bachelor's degree. This workforce training program will partner with the industry to develop employer-led sector partnerships who will help design training programs and, importantly, will serve as hosts for internships, apprenticeships, and other work-based learning opportunities. Additionally, the program will establish regional training centers at Halifax Community College, Martin County Community College, Guilford Technical Community College, UNC-Charlotte, and Olympic High School in Charlotte.

The STEPs4GROWTH program builds upon North Carolina's Clean Energy Youth Apprenticeship (CEYA) program developed through a partnership between the North Carolina Business Committee for Education, NC A&T, and NCDEQ. CEYA supports high school, community college, and university students from underserved communities to develop careers in the clean energy industry. In the summer of 2020, CEYA implemented energy efficiency pilots in Guilford and Wake Counties. CEYA also launched the nation's first solar apprenticeship program in partnership with Halifax County Schools, Halifax Community College, and the Center for Energy Education. Students received industry-recognized credentials and paid work-based learning through these programs. EO 246 outlined efforts to grow the CEYA program in five additional sites.

### Climate Change Workforce Diversity Report

EO 246 calls for the North Carolina Climate Change Interagency Council (Climate Council) to identify strategies for increasing workforce diversity in industries and occupations that have a role in addressing climate change in North Carolina. In June 2022, the Climate Council appointed Dr. Greg Monty, Professor at NC A&T and Director of the Center for Energy Research and Technology, to chair a workgroup leading this effort. This workgroup of economic development experts, State agency representatives, educational partners, and other stakeholders developed the final Climate Change Workforce Diversity Report which includes 11 recommendations and 30 strategies across four key areas:

1. Career awareness and education
2. Employer engagement
3. Policy
4. Community engagement and measurement

The report also highlights existing programs to continue and expand including CEYA, the North Carolina Business Committee for Education's work-based learning Navigator, and the Workforce Resilience grants (which support community college students earning short-term credentials). The workgroup will continue to help implement the identified strategies in the report.

### Offshore Wind Job Development

EO 218 established the NC TOWERS. This Taskforce provides expert advice to Governor Cooper and State policymakers on ways to advance offshore wind energy projects in North Carolina, focusing primarily on economic development and job creation.

NC TOWERS works to:

- Identify economic and workforce opportunities and challenges presented by the offshore wind industry
- Recommend policies and programs to capture strategic opportunities that foster a thriving offshore wind workforce and business community
- Provide advice for developing the State's offshore wind supply chain, workforce, and infrastructure
- Foster and support environmental justice and equitable access to opportunities for underserved communities
- Recommend policies and guidelines that prioritize offshore wind energy projects.

The Workforce Subcommittee of the Task Force conducted a job skills analysis to identify the skills most needed to prepare individuals to work in construction and installation occupations within the offshore wind industry.

Due to North Carolina's strong manufacturing presence, workers are well positioned to transition to manufacturing jobs within the offshore wind industry by levering their transferrable skillsets. Other jobs, however, require specific training and skills. Construction and installation occupations are expected to make up 41% of the direct offshore wind workforce. Therefore, preparation now to identify the skill sets needed for construction and installation occupations is fundamental.

Commerce's Labor and Economic Analysis Division (LEAD) identified 20 occupations within construction and installation jobs and identified the knowledge, skills, and abilities required within those key occupations. LEAD then identified associated occupations with transferable knowledge, skills, and abilities that are already prevalent in North Carolina. Then, LEAD identified the current supply of labor force in those key occupations and compared it to full-time equivalent projections from the National Renewable Energy Laboratories (NREL) workforce study to identify workforce and training gaps. In 2023, the NC TOWERS Workforce Subcommittee will use the workforce projections to recommend training programs to fill the labor gaps to meet the offshore wind industry needs.

### Preparing North Carolina K-12 Teachers and Students for a Resilient, Clean Energy Economy

The Kenan Fellows Program for Teacher Leadership at NC State University addresses the need for professional development for educators and is the largest science, technology, engineering, and math (STEM)-focused teacher leadership program in North Carolina. Since 2000, the program has selected K-12 teachers statewide for a work-based learning program that bridges the professional worlds of education and industry.

Just as technology advancements in clean energy are inspiring innovation and investment into training the current workforce, they are also changing expectations for K-12 educators about how to best prepare students for the future. To better support public school teachers, NCDEQ has made a five-year commitment to fund the Kenan Fellows Clean Energy Program. Part of the Keenan Fellows for Teacher Leadership at NC State University, this program addresses the need for professional development for educators and is the largest STEM-focused teacher leadership program in North Carolina. The Clean Energy program will select K-12 teachers statewide to participate in a work-based learning program that bridges the professional

worlds of education and industry and develops new hands-on curriculum materials for peer-to-peer training programs. The inaugural cohort is set to begin Summer 2023.

### United Kingdom Clean Energy Memorandum of Understanding

In July 2022, Governor Roy Cooper and the United Kingdom Minister for International Trade Penny Mordaunt signed a Memorandum of Understanding on Cooperation and Trade Relations to strengthen economic ties and transition to a clean energy economy. To reach shared climate, clean energy, and environmental justice goals, North Carolina and the United Kingdom intend to share information and best practices, conduct missions with government officials, facilitate partnerships among private-sector companies, connect institutions of higher education, collaborate on events, and explore opportunities to increase investment in key sectors. The Memorandum is being implemented through a working group with participants from North Carolina and the United Kingdom.

## *Federal Support*

Recent federal leadership has significantly bolstered North Carolina's efforts to equitably grow the clean energy economy, build the clean energy workforce, and reduce pollution. Over the past two years, Congress and the Biden Administration have authorized the largest ever federal investments in clean energy and climate resiliency infrastructure. Through the Justice40 Initiative, the Biden Administration established a goal for 40% of certain federal investments to be directed toward communities that are marginalized, underserved, and overburdened by pollution.

In November 2021, President Biden signed the Bipartisan Infrastructure Law (BIL) including unprecedented investments in broadband, rail and transit, clean energy, and water infrastructure. The BIL allocated funding to over 350 programs across more than a dozen federal departments and agencies to support projects like building out electric vehicle charging networks and replacing lead service water lines. Under the BIL, North Carolina will receive hundreds of millions of dollars that will support the State's ongoing climate and clean energy priorities. Examples include[16]:

- Electric vehicle charging: As part of the National Electric Vehicle Infrastructure Program, North Carolina received $109 million in formula funding to support the expansion of electric vehicle charging in the State. The North Carolina Department of Transportation (NCDOT) is administering these funds and expects to start issuing State awards in 2023.
- Clean buses: The BIL has invested over $10 billion for clean public transit and school buses. To date, North Carolina has been awarded $12.2 million from the Environmental Protection Agency's Clean School Bus Program. The State has also received $23.7 million for clean transit buses and improved bus service through the Department of Transportation's Low- and No- Emission Bus and Bus Facilities Program. $18.3 million has been awarded to clean transit vehicles and charging infrastructure through the Department of Transportation's Buses and Bus Facilities Program.

[16] North-Carolina-BIL-State-Fact-Sheet-Nov-22.pdf (whitehouse.gov)

- Carbon Reduction Program: North Carolina received $172 million in formula funding to reduce transportation emissions and develop carbon reduction strategies in the transportation sector.
- Clean energy: To date, approximately $359 million has been allocated to North Carolina for clean energy, energy efficiency, and electricity in 2022. This includes:
  - $89.8 million for weatherization
  - $10.4 million to the State Energy Program
  - $10.6 million to prevent outages and make the electricity grid more resilient
  - $250 million in awards to two companies in North Carolina that will strengthen the battery supply chain
- Resilience: Approximately $139 million has been allocated to North Carolina for infrastructure resiliency in 2022, including $23.2 million through the Army Corps of Engineers for flood mitigation.

In August 2022, President Biden signed the Inflation Reduction Act of 2022 (IRA) into law, marking the federal government's largest-ever investment of nearly $370 billion through tax credits, loans, formula funds, competitive grants and other programs to grow the domestic clean energy economy, reduce GHG emissions and other pollution, and advance environmental justice for underserved communities. While impacted federal agencies are still soliciting public comments and developing guidance for most programs in the IRA, many of the funding opportunities will directly support North Carolina's identified needs and priorities discussed throughout this report.

## Climate Adaptation and Resilience

Climate adaptation and resilience efforts are not the primary focus of the Pathways Analysis but will nevertheless be invaluable to help ensure the prosperity and safety of current and future generations.

EO 80 directed NCDEQ to prepare a North Carolina Climate Risk Assessment and Resiliency Plan (Resilience Plan), which recommends measures to improve resilience in communities and government in North Carolina and includes four elements:

1. North Carolina Climate Science Report
2. State Agency Resilience Strategies
3. Statewide Vulnerability Assessment and Resilience Strategies
4. North Carolina Enhanced Hazard Mitigation Plan

NCDEQ engaged a group of climate scientists to develop the ***North Carolina Science Report*** *(NCSR)* in 2020, an independent and peer-reviewed assessment of historical climate trends and potential future climate changes in North Carolina under increased GHG concentrations. The report includes an overview of the physical science of climate change and detailed information on observed and projected changes in temperature and precipitation averages and extremes, hurricanes and storms, sea levels, and other relevant climate metrics.

The NCSR highlights that climate change is already being felt in North Carolina and that the State will continue to experience significant challenges, such as more intense storms and flooding, dangerously high

temperatures, droughts, rising sea levels and beach erosion, and harm to ecosystems and wildlife. Scientists agree that the changes to North Carolina's climate in this century will be larger than anything experienced in the State's history, with impacts that will continue to threaten the health, safety, and well-being of the State's people, economy, and environment. The extent and severity of future warming and associated impacts will depend on how quickly the emissions of heat-trapping gases is curtailed.

The Resilience Plan identified the North Carolina Office of Recovery and Resiliency (NCORR) as the lead agency to manage efforts and prioritize and implement resilience recommendations from the plan across the state. Cabinet agencies publish annual updates to report resilience activities and progress toward implementation of the Resilience Plan.

### Resilience Plan Highlights

The N.C. Resilient Communities Program, created in partnership by NCORR and NCDEQ, is a notable Resilience Plan initiative. The program consists of NCORR's Regions Innovating for Strong Economies & Environment (RISE) program and NCDEQ's Resilient Coastal Communities Program (RCCP), which are designed to help North Carolina communities build resilience to the impacts of climate change and reduce damages from future disasters such as hurricanes, flooding, and wildfires. These agencies are boosting local resilience by providing expertise, technical support, and funding to communities as they develop resilience strategic plans, prioritize local resilience projects, and design and construct priority projects.

Other steps State agencies have taken to implement the recommendations of the Resilience Plan include:

- Adopting rules that encourage and incentivize long-term beach planning, development siting, and beneficial use of dredged material
- Amending the Coastal Habitat Protection Plan to include climate change and coastal resilience strategies
- Becoming a national leader in preventing and mitigating risks of high-hazard dams overtopping during storm and flooding events
- Launching the Tribal Coastal Resilience Connection Project to address climate vulnerabilities identified by tribal communities living in the shared waterways of the Albemarle-Pamlico estuary
- Initiating activities to combat heat-related illness including implementing heat-health alert systems in Eastern North Carolina
- Identifying and protecting cultural and archeological resources vulnerable to flooding, storm damage, or sea level rise
- Deploying programs to elevate, relocate, or buyout individual and commercial properties located in floodplains with significant vulnerability to flooding and storm damage

In addition to these initiatives, the State is also updating the North Carolina Hazard Mitigation plan to better reflect climate risks, vulnerabilities, and interdependencies across infrastructure and sectors. Anticipated to be finalized in early 2023, the North Carolina Hazard Mitigation Plan will help the State, regions, and local governments develop long-term strategies for protecting people and property, and build-back-better in the aftermath. Adaptation and mitigation are critical to ensuring resilience and breaking the cycle of destruction and reconstruction.

### Other Resiliency Initiatives

Additional actions taken beyond the Resilience Plan include Governor Cooper's Executive Order No. 266 (EO 266) to improve the resilience of State-owned buildings against flooding. EO 266 builds upon the Resilience Plan by directing the North Carolina Department of Administration (DOA) to work with stakeholders to update the State's Uniform Floodplain Management Policy with the objectives of comprehensively assessing and mitigating risks for state construction; minimizing flood damage to State-owned assets; considering the impacts of sea-level rise and climate change; and supporting natural hydrologic conditions and the beneficial services provided by natural infrastructure. EO 266 also directs the NCDOA to work with stakeholders to examine whether the Uniform Floodplain Management Policy should be applied to all State-funded construction projects, beyond just State-owned construction projects.

In 2021, the General Assembly allocated $20 million to NCDEQ's Division of Mitigation Services to develop North Carolina's first statewide Flood Resiliency Blueprint (Blueprint) for major watersheds impacted by flooding. The Blueprint will form the backbone of a State flood planning process that increases community resiliency, provides a resource for riparian (riverbank) management to reduce flooding, and support the establishment and furtherance of local government stormwater maintenance programs. The Blueprint will create a documented process for conducting flood resiliency planning at multiple scales and, ultimately, is also intended to lead to a prioritized set of projects and funding strategies that the State and other government entities can implement. The draft of the Blueprint and the Neuse River Basin action strategy is due by December 31, 2023. The General Assembly also allocated $96,142,500 to NCDEQ for flood resiliency projects in targeted river basins after the completion of the draft Blueprint. As the pilot watershed, the Neuse River Basin Action Strategy will be the first application of the Blueprint in North Carolina. Once the draft Blueprint is approved, it will be applied to other targeted river basins in 2024.

# Modeling Net-Zero Pathways in North Carolina

## Introduction to Modeling

### Project Development

Consulting firm Energy and Environmental Economics (E3) conducted the technical modeling for the Pathways Analysis in consultation with the North Carolina Governor's Policy Office, Interagency Steering Committee, the Technical Advisory Group (TAG), other targeted stakeholders, and the general public (see Appendix A Supplemental Information on Stakeholder Engagement for more). The Governor's Office led all decision making on scenarios and assumptions for the analysis. The Interagency Steering Committee, composed of members of the State agencies relevant to the analysis, provided data, subject matter expertise, and input on key decision points. These decision points included scenario design, inputs and assumptions, and modeling approach throughout the analysis to ensure the analysis is aligned with parallel efforts such as the Clean Transportation Plan process. The TAG played a critical role in providing technical feedback at key decision points to keep the analysis informed by subject matter expertise. The general public and other targeted stakeholders received status updates on progress and provided timely feedback throughout the analysis.

### Modeling Approach

E3 developed an analytical model of all of GHG sources and sinks in North Carolina; GHG sources include electric power plants and gasoline-powered vehicles; GHG sinks include North Carolina's forests that absorb carbon dioxide ($CO_2$) throughout the year. This modeling approach- referred to as "PATHWAYS" was conducted in three core steps illustrated in Figure 12.

1. Measuring the current state of emissions based on the 2022 Inventory
2. Estimating future emissions based on current trends and existing policy through the modeling of the Reference Scenario
3. Evaluating the impact of new potential measures and actions that would help the State meet climate goals through the modeling of multiple Net-Zero Scenarios

***Figure 12.*** *Key Steps of the PATHWAYS Model Analysis*

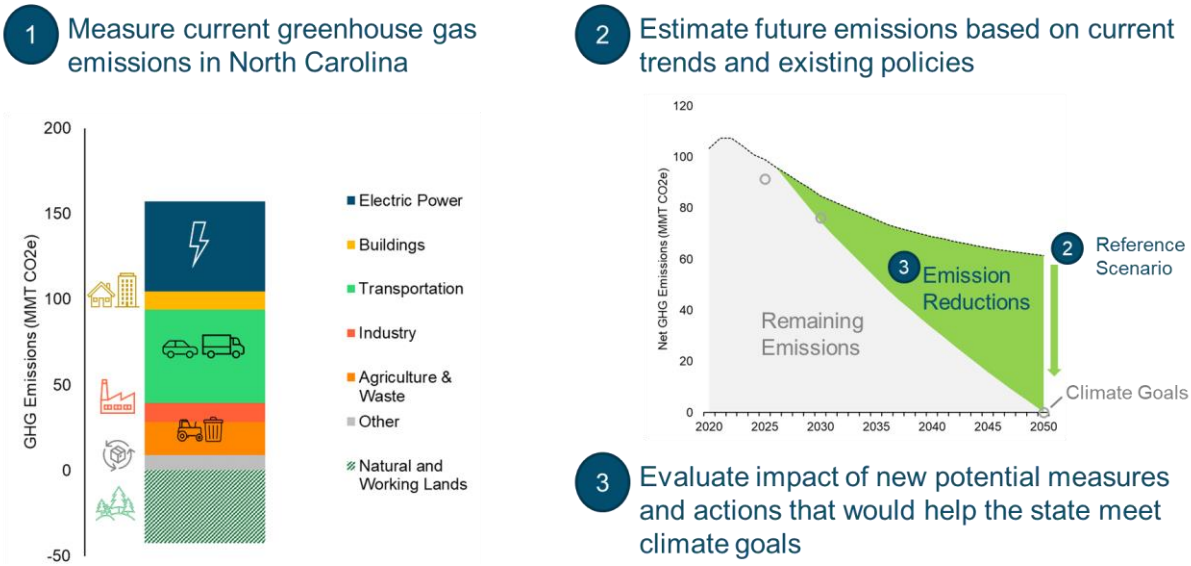
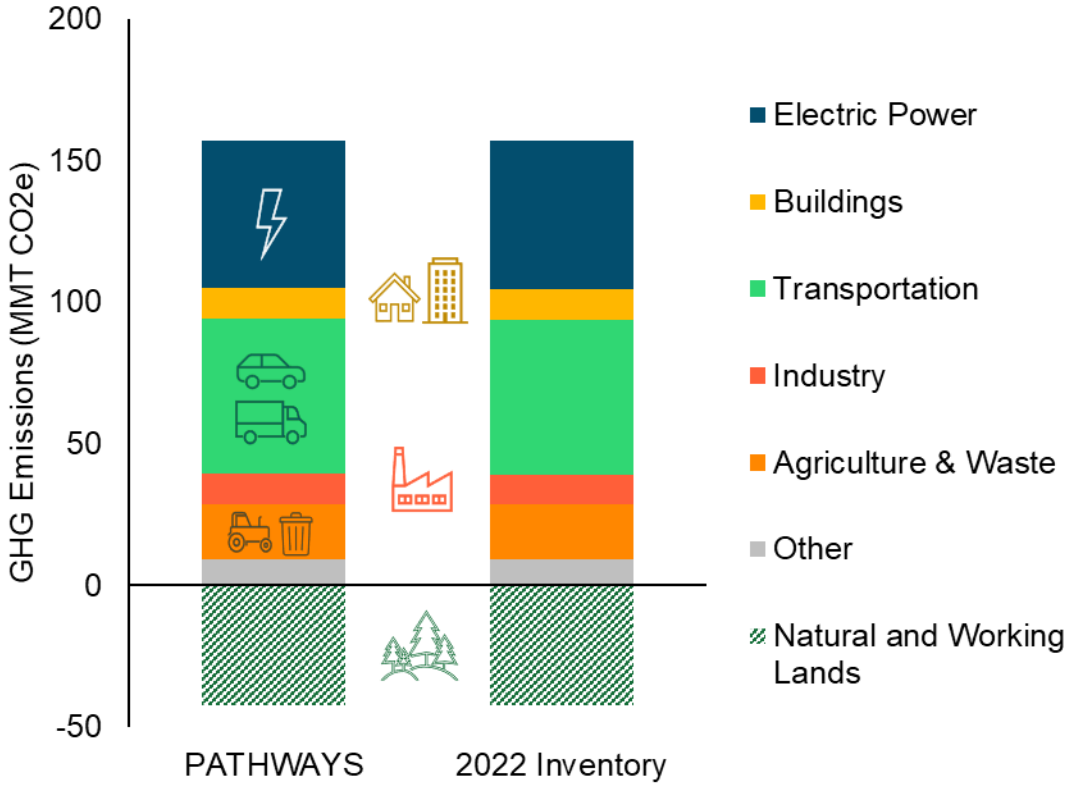



***Figure 13.*** *Current North Carolina Gross Greenhouse Gas Emissions by Subsector, Based on 2022 Inventory*

Current statewide gross GHG emissions[17] total 159.5 MMT $CO_2e$[18], of which energy combustion activities from transportation, electricity generation, industry, and buildings account for over 80% of emissions (see Figure 13). Transportation is the largest source sector. It is responsible for over one-third of total gross emissions, with the majority of the emissions coming from on-road passenger vehicles and trucks. Electricity generation closely follows as the second largest source sector responsible for another one-third of total gross emissions, mainly from in-State generation. The remaining one-third of total gross emissions are from fuel combustion in buildings and industry and non-combustion emissions from agriculture, waste, industrial processes, and fugitive methane emissions from natural gas transmission and distribution. In addition to gross emissions, there are carbon sinks from land use, land-use change, and forestry, with a current net total of -42.1 MMT $CO_2e$. E3's PATHWAYS model is fully benchmarked to the 2022 NC GHG Inventory for GHG emissions (see Figure 14) and final energy demand. Total emissions in PATHWAYS are within <1% of the *2022 Inventory*[19].

***Figure 14.*** *Benchmarking of Greenhouse Gas Emissions in E3's PATHWAYS Model to 2022 Inventory*




[17] North Carolina's current emissions profile, as shown in **Figure 13**, is based on the latest *2022 Inventory*. All GHG emissions associated with consumption of electricity in buildings, industry, and transport are accounted for in the "Electric Generation" category.

[18] Carbon dioxide equivalent ($CO_2e$) represents a translation of the impact of all greenhouse gases on climate change into units of $CO_2$. This analysis uses 100-year global warming potentials (GWPs) from IPCC's Fourth Annual Report (AR4) for this translation, which matches the modeling approach for the *2022 Inventory*.

[19] E3 made one methodological change from the *2022 Inventory* when calculating energy demand and GHG emissions for 2018. A small amount of diesel and gasoline consumption for farm and construction vehicles was removed from the transportation sector, as this consumption is likely also being counted in the industrial fuel consumption data. This adjustment only changes 2018 gross GHG emissions by ~1% in 2018.

Starting with current emissions, E3 further developed future scenarios of North Carolina's GHG emissions. This included the Reference Scenario, where no additional action is taken beyond existing policies and trends. It also included the Net-Zero Scenarios, where the State takes significant new action to achieve its GHG targets. The PATHWAYS model is an economy-wide accounting tool that captures all GHG sources and sinks as it tracks key mitigation actions across all sectors over time (see Figure 15). A key feature of the PATHWAYS model is the stock rollover function that captures "infrastructure inertia" reflecting lifetimes and vintages of key equipment: building appliances and on-road vehicles. The model allows for rapid comparison between scenarios that test the impact of current policies and technology trends and various priority actions on reaching mid-term and long-term climate targets. Within the PATHWAYS modeling framework, the Net-Zero Scenarios are defined by key measures that reduce energy consumption or emissions intensity of activities across various sectors of the economy, as shown in Table 1.

*Cost and Technology Readiness*

This PATHWAYS analysis focuses primarily on viable technological paths to meet North Carolina's goals, which includes careful scenario design to ensure ambitious but realistic timing of investments and reliance on technologies that can be commercialized in the next 30 years. The analysis does not explicitly model costs of decarbonization scenarios, but it leverages E3's decade-long experience conducting economy-wide pathways analyses and includes an assessment of technologies that are demonstrated to be at a relatively high readiness level and can be deployed cost-effectively (see section titled: Long-Term (2035-2050) – Deploy the Next Phase of Solutions).

***Figure 15.*** *Overview of PATHWAYS Model*

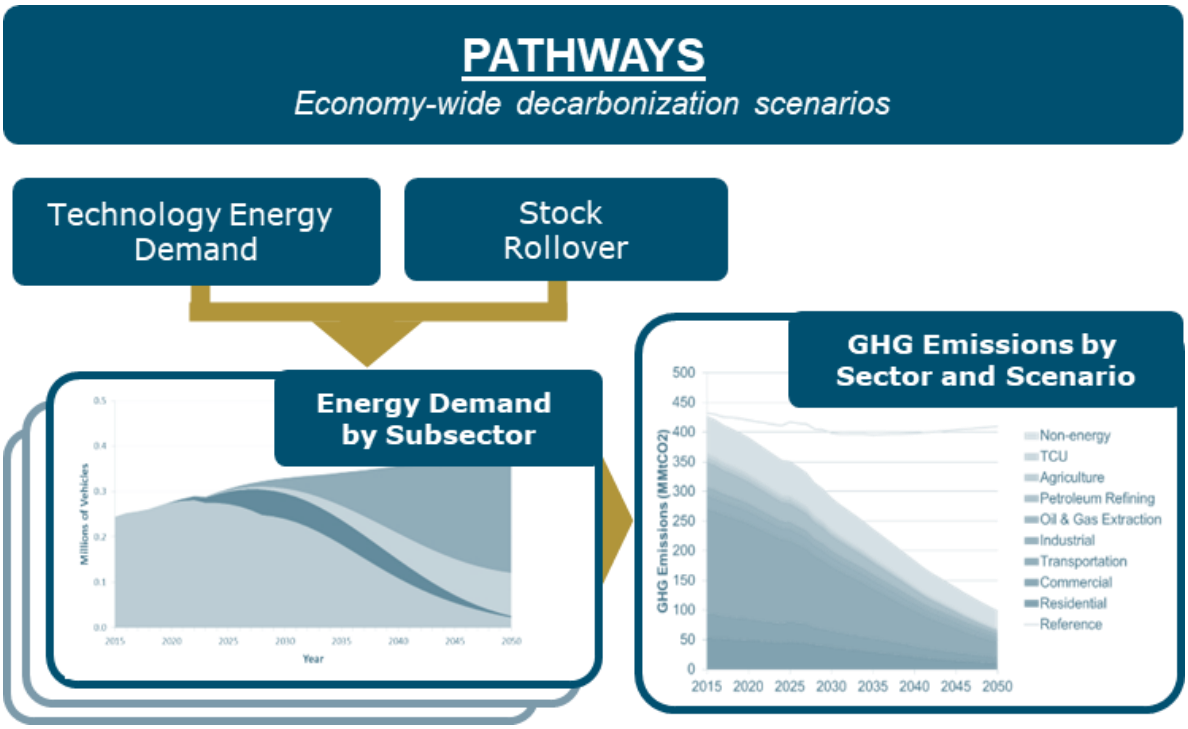


***Table 1.*** *Priority Actions that Impact Emissions*

| | |
|---|---|
| Buildings | ▪ Increased sales of high efficiency appliances<br>▪ Improved building shells in both new and retrofit buildings<br>▪ All-electric new construction standards<br>▪ Increased sales of electrified devices for all end uses (space and water heating, drying, cooking) |
| Transportation | ▪ Improved fuel economy for new vehicles sold<br>▪ Reductions in vehicle-miles traveled through transit and smart growth<br>▪ Increased sales of ZEVs, including battery-electric and hydrogen fuel cell vehicles |
| Clean Electricity | ▪ Scale up of renewable electricity sources (wind and solar) and battery storage<br>▪ Targeted role for zero-carbon firm generation that can provide electricity at any time (e.g., hydrogen combustion, advanced nuclear technologies) |
| Decarbonized Fuels | ▪ Production of advanced biofuels with sustainable biomass feedstocks<br>▪ Production of green hydrogen through electrolysis using renewable electricity |
| Carbon Sequestration | ▪ Reforestation and restoration to enhance carbon sinks from natural and working lands<br>▪ Application of negative emissions technologies such as direct air capture of CO2 |

## Reference Scenario

The Reference Scenario builds on the *2022 Inventory* by incorporating emission projections for previously unaccounted for policies enacted after 2020. Including these more recent updates, **the Reference Scenario shows that North Carolina is on track to reduce GHGs by 37% by 2025, 46% by 2030, and 60% by 2050, relative to the 2005 baseline.** The following key trends and policies were modeled in the Reference Scenario (see Figure 16 for the key measures modeled in the Reference Scenario):

+ **HB 951:** 70% reduction in electricity generation $CO_2e$ from large utilities' in-state generation by 2030, with net-zero emissions by 2050
+ **Federal Corporate Average Fuel Economy (CAFE) standards:** Recently announced fuel economy standards for passenger cars and light trucks in model years 2024-2026
+ **Federal Hydrofluorocarbon (HFC) phasedown:** Recently finalized EPA regulation, authorized under the American Innovation and Manufacturing (AIM) Act, phasing down HFC, a widely used substitute for ozone-depleting substances as refrigerants and a highly potent GHG
+ **Inflation Reduction Act (IRA):** Impacts of the IRA are estimated for adoption of residential heat pumps, electric vehicles, and hydrogen fuel switching in some industrial applications[20]

[20] Direct impacts of Inflation Reduction Act on clean electricity generation were excluded from this analysis since the impact of **HB 951** on electricity emissions is also included and there is no detailed electric sector modeling in this analysis.

***Figure 16.*** *North Carolina Greenhouse Gas Emissions Reduction Measures in the Reference Scenario*

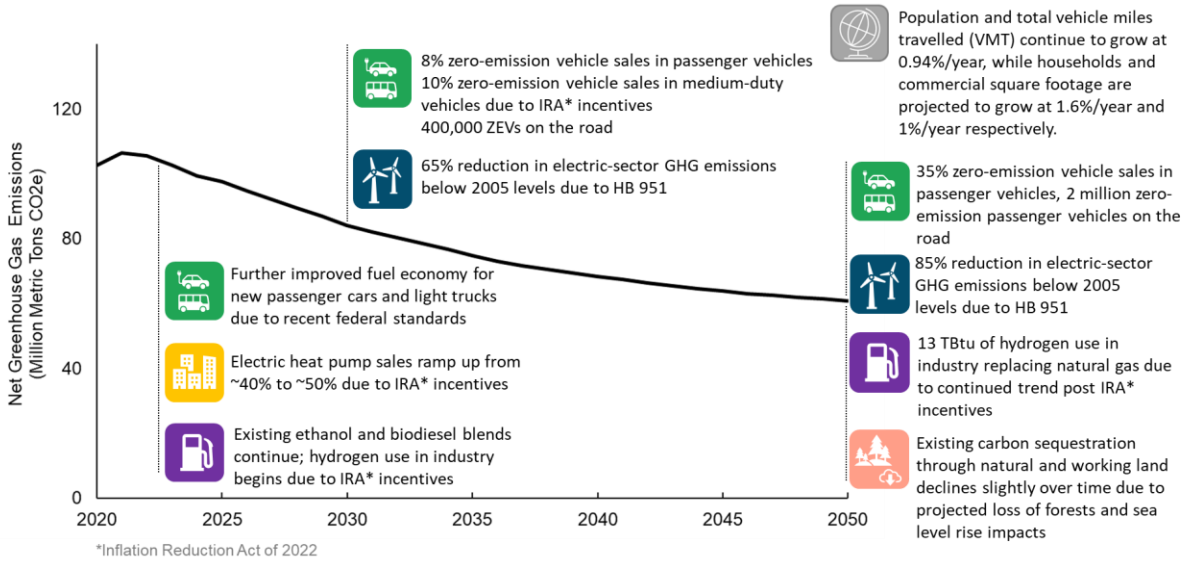
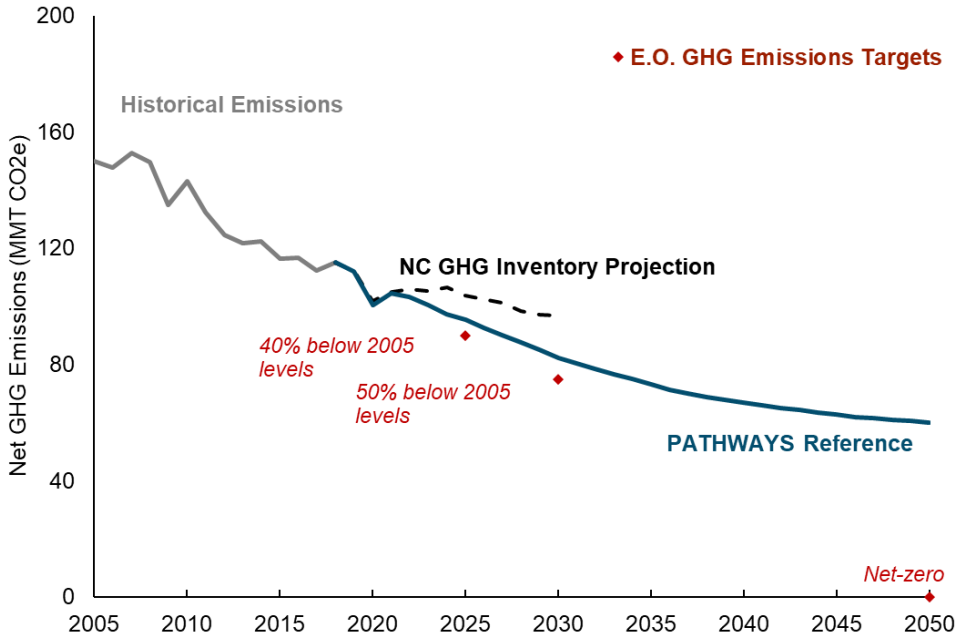



Figure 17 shows that GHG emissions are lower in the PATHWAYS Reference Scenario than in the 2022 Inventory Projection through 2030. This discrepancy is mainly due to inclusion of HB 951 for the electric sector, the recent federal CAFE and HFC policies, and IRA impacts, none of which are included in the *2022 Inventory* projection due to its publication date relative to the effective date of these measures.

***Figure 17.*** *Net Greenhouse Gas Emissions Projection from the PATHWAYS Reference Scenario*



The Reference Scenario shows that North Carolina is on track to reduce emissions over time, but there are still gaps between existing policies and what it takes to achieve the State's near- and long-term climate targets. To reach net zero by 2050, more work needs to be done.

## Net-Zero Scenario Design

The Governor's Office designed three Net-Zero Scenarios, or "pathways," which all achieve net-zero GHG emissions across all sectors of North Carolina by 2050. The objective of this analysis was not to choose a specific pathway. Rather, the variances between pathways are designed to help policymakers and stakeholders understand the biggest opportunities to reduce emissions and sequester carbon as well as explore tradeoffs between different emission-reduction strategies.

All scenarios include key measures covering all sectors of North Carolina's economy with common focus on energy efficiency, electrification and decarbonization of electricity as shown in Figure 18. However, each scenario takes a different approach to achieving incremental GHG emissions reductions in North Carolina. Figure 19 shows how the key measures are similar or different across the scenarios illustrated by level of transformation compared to today.

- The High Electrification Scenario tests higher levels of electrification in buildings, transportation, and industry to achieve the State's decarbonization targets.
- The High Decarbonized Fuels Scenario tests a larger role for advanced decarbonized fuels, such as advanced biofuels[21] and green hydrogen[22], to supplement moderate levels of electrification.
- The High Carbon Storage Scenario explores what volume of carbon offsets would be needed to achieve net zero either from lands and forests or through negative emissions technologies (NETs)[23] under moderate levels of electrification and without relying on decarbonized fuels.

[21] Advanced biofuels in this scenario are only produced using biomass wastes and residues from existing economic activities (e.g., methane from existing landfills, leftover residues from agricultural yields, etc.) based on the feedstock potential identified in North Carolina through the Department of Energy Billion Ton Report: https://www.energy.gov/eere/bioenergy/2016-billion-ton-report. Purpose-grown biomass produced specifically for use as energy crops were excluded due to concerns around sustainability and potential conflicts with land use for agriculture and other economic activities.

[22] Green hydrogen is produced through electrolysis powered by renewable electricity. This can be compared to other methods of hydrogen production such as gray hydrogen (produced through steam methane reforming [SMR] of natural gas) or blue hydrogen (SMR with carbon capture).

[23] NETs include any technology that produces negative GHG emissions. Commonly modeled NETs are direct air capture of $CO_2$ (DAC) or sustainably grown bioenergy with CCS (BECCS).

***Figure 18.*** *Key Measures for Deep Decarbonization*

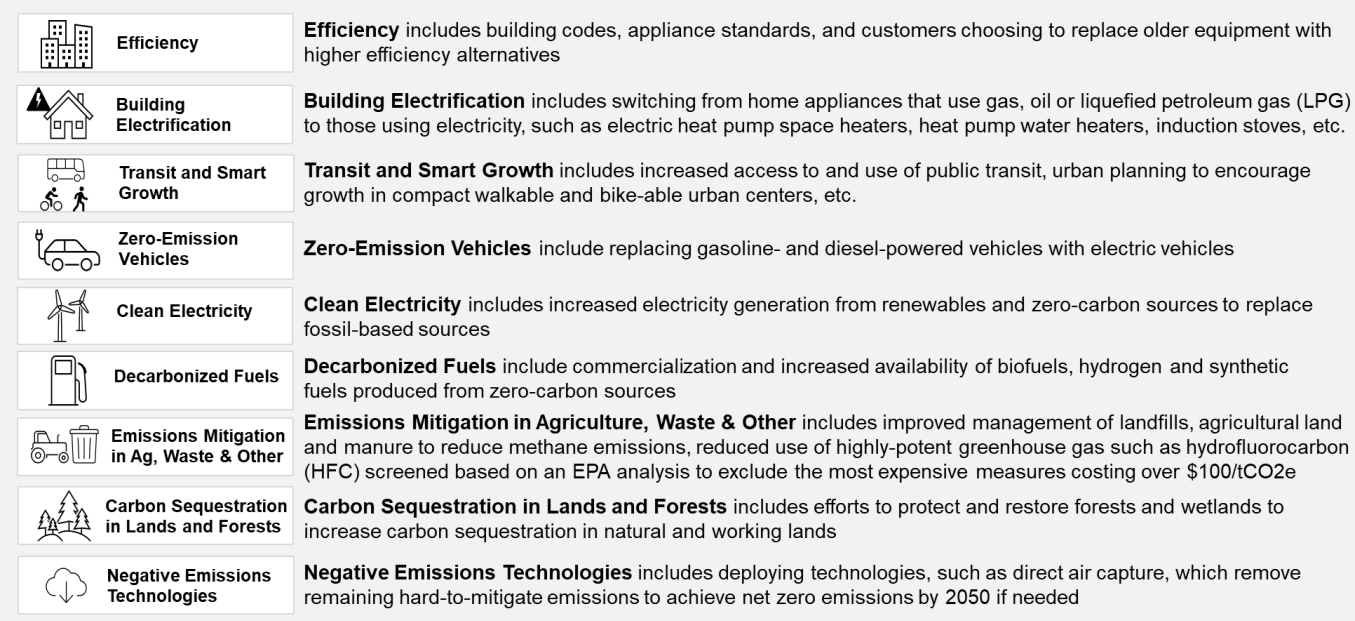
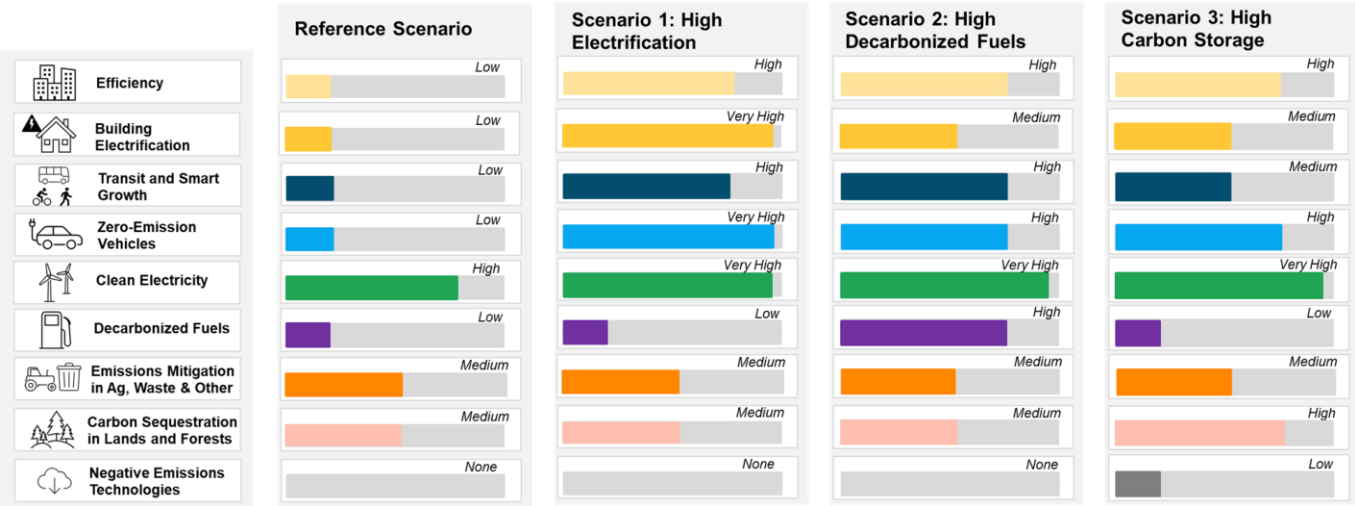
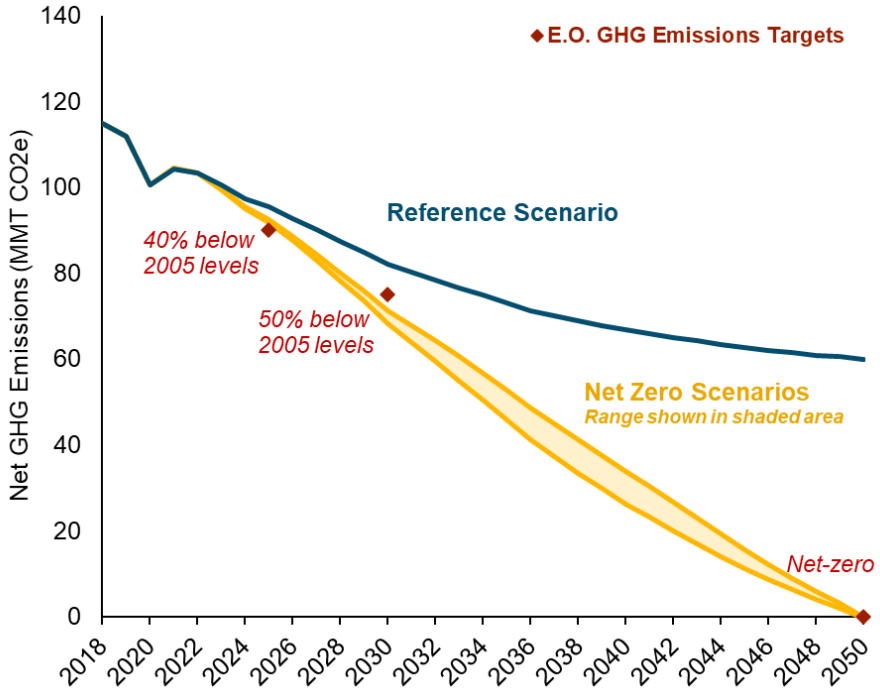



***Figure 19.*** *Net-Zero Scenario Design: Level of Transformation by Measure*



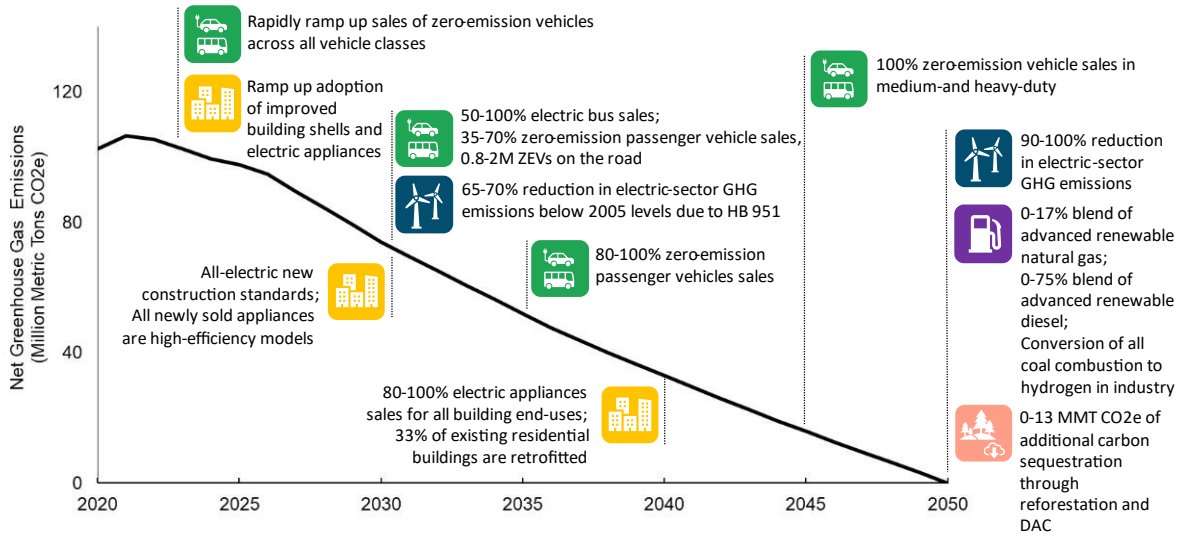

All three scenarios achieve net-zero GHG emissions by 2050 (see Figure 20), though each scenario relies on a different mix of mitigation technologies and intensity of implementation. The Net-Zero Scenarios have a similar impact on the total net emissions but have different implications for the nature and timing of the energy system transition in North Carolina. In addition, all the scenarios are within 1% of the 2025 GHG target of a 40% reduction below 2005 levels, and they all overachieve the 2030 target of a 50% reduction on their path to 2050.

***Figure 20.*** *Net GHG Emissions by Scenario*




All Net-Zero Scenarios include different levels of key mitigation actions across sectors. The key differences across the scenarios (see Figure 21) are the pace of electrification of buildings and vehicles, the level of clean electricity, and the use of advanced biofuels and additional carbon sequestration to help achieve net zero by 2050. Regardless of the differences, all scenarios commonly feature a rapid ramp-up of building and vehicle electrification; a wide adoption of efficiency measures that improve appliance performances, building shells, reducing vehicle miles traveled; and deep decarbonization of electricity generation.

***Figure 21.*** *North Carolina GHG Emissions Reduction Measures: Net Zero Scenario Ranges*




# Key Scenario Assumptions and Results

## Economy-Wide GHG Emissions

Figure 22 shows historic GHG emissions in 2005 and projected 2050 emissions for each net-zero pathway by economic sector. In addition to achieving net-zero GHG emissions by 2050, the three net-zero scenarios also achieve between 73-80% reductions in gross GHG emissions relative to 2005 by 2050. The remaining 40-50 MMT of gross emissions in 2050 are offset by North Carolina's forests that act as large natural carbon sinks and (in the case of the High Carbon Storage Scenario) negative emissions technologies, assumed in this study to be DAC. Figure 22 shows the remaining emissions by sector in 2050 compared to 2005 baseline emissions. Natural sinks in the High Electrification and High Decarbonized Fuels Scenarios (shown in shaded green as negative emissions) offset 40 MMT $CO_2e$ of remaining gross emissions, while the High Carbon Storage scenario offsets 50 MMT $CO_2e$ through a combination of increased natural sinks and DAC.

***Figure 22.*** *Remaining Emissions in 2050 by Scenario, Compared to 2005 Baseline Emissions*

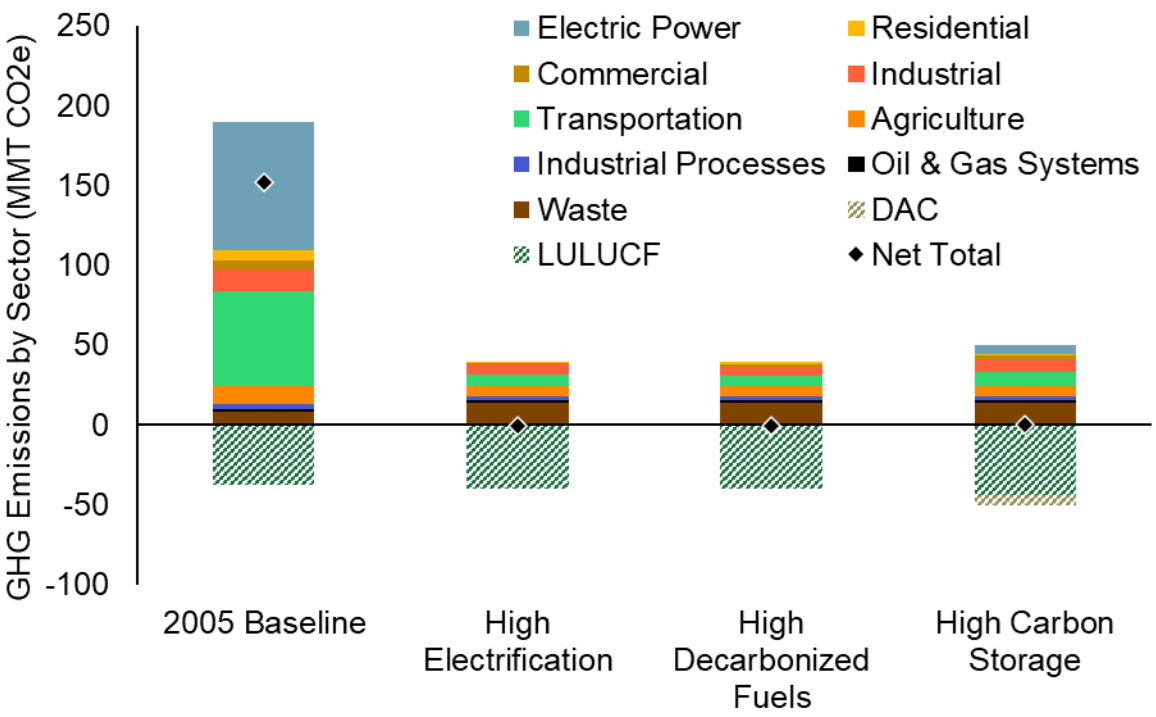



Table 2 shows the percent reduction in GHG emissions by sector relative to 2005 levels for the three Net-Zero Scenarios. Sector-specific assumptions and modeling results will be discussed in the following sections of the report. In general, all three scenarios are similar in terms of their level of reduction by sector. The electric power sector has the deepest reductions, followed by the residential and transportation sectors (all achieve at least an 85% direct reduction in GHGs). Next, the commercial and industrial sectors have ambitious but delayed reductions compared to those of the electric power, residential, and transportation sectors due to diverse applications, technology readiness of solutions, and cost sensitivity of the industries, with these sectors mostly achieving between 50-70% reductions (the commercial sector in the High Electrification Scenario and industrial sector in the High Carbon Storage Scenario are outliers). Finally, reductions in the non-energy, non-combustion sectors are the same for all net-zero scenarios and are notably smaller than reductions in the energy sectors due to the difficulty in mitigating emissions from non-energy sources. In the case of the waste sector, emissions actually continue to increase over time relative to 2005; however, the 2050 emissions for the three net-zero scenarios are still lower than waste sector emissions in the Reference Scenario in that year. This result is driven by a continuing growth rate for waste emissions based on historical trends that were used in the *2022 Inventory*, along with relatively little abatement potential for waste emissions identified by EPA in their analysis of non-$CO_2$ emissions in North Carolina[24].

[24] Mitigation potential for all agriculture, oil and gas systems, and waste sectors comes from EPA State-level analysis of non- $CO_2$ GHG emissions mitigation potential, with a cost screening applied to only include measures below \$100/t$CO_2$e: https://cfpub.epa.gov/ghgdata/nonco2/usreports/

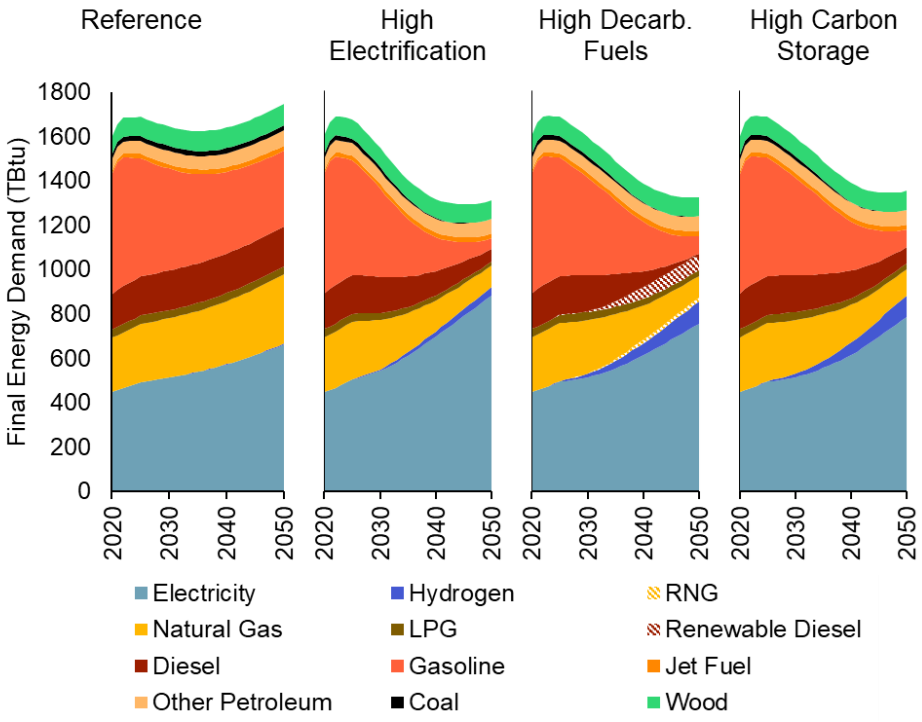
***Table 2.*** *Reduction in Gross GHG Emissions by 2050 for Each Sector Below 2005 Levels*

| Sector | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|
| Electric Power | 100% | 100% | 93% |
| Residential | 94% | 87% | 85% |
| Commercial | 82% | 68% | 61% |
| Industrial | 53% | 57% | 40% |
| Transportation | 88% | 89% | 85% |
| Agriculture | 42% | | |
| Industrial Processes and Product Use | 26% | | |
| Oil & Gas Systems | 14% | | |
| Waste | -68%[25] | | |

## Economy-Wide Energy Demand

Figure 23 shows final energy demand over time for all scenarios. After a near-term increase in 2021 and 2022 (mostly due to a rebound in transportation fuel use following the COVID-19 pandemic), energy demand in the Reference Scenario declines slightly though the 2030s, mostly due to fuel economy

***Figure 23.*** *Final Energy Demand by Fuel, by Scenario*



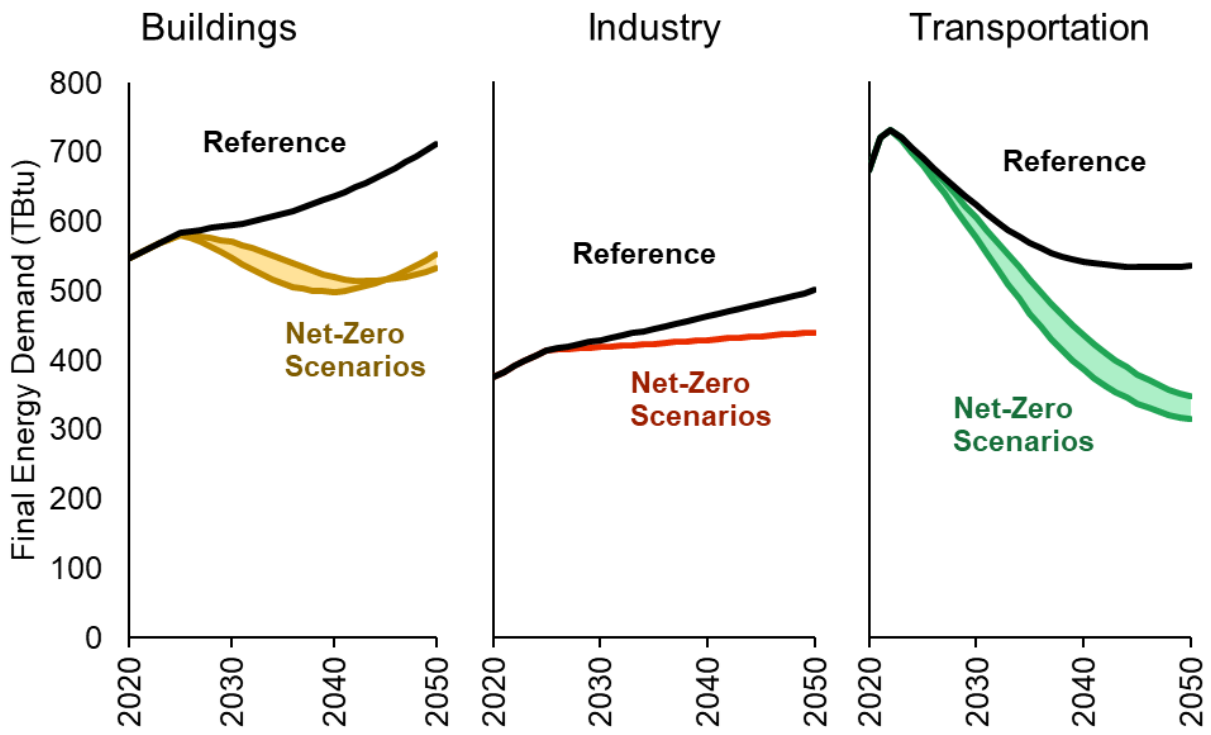

[25] While waste sector emissions are higher in 2050 in the net-zero scenarios than those in 2005; they are still 9% lower than the Reference Scenario waste emissions in 2050.

standards and electric vehicle adoption for light-duty vehicles (LDVs), before picking back up again as efficiency improvements slow and economic and population growth continues.

All three Net-Zero Scenarios see a significant reduction in fossil fuel demand and large increases in electricity demand along with smaller increases in demand for decarbonized fuels like emissions-free hydrogen (e.g., green hydrogen produced via electrolysis powered by renewables) and advanced biofuels. In addition, total energy demand in 2050 in the three Net-Zero Scenarios is around 25% lower than that in the Reference Scenario. This is in part due to conventional energy efficiency measures for buildings, transportation, and industry, but is mostly due to the embedded efficiency of electrification, as heat pump electric space heaters and vehicles are more efficient at the device level than traditional combustion-based technologies. Over the course of the study period, electrification of end uses powered by fossil fuels and conventional energy efficiency measures account for around 60% and 40% of the reduction in total energy demand, respectively.

Figure 24 below shows the range of final energy demand by sector for the net-zero scenarios compared to the Reference Scenario. Both the buildings and transportation sector have particularly large reductions in final energy demand, driven by the deployment of heat pumps to replace electric resistance and natural gas heaters as well as battery electric vehicles replacing internal combustion engine vehicles, respectively.

***Figure 24.*** *Final Energy Demand by Sector for the Reference and Net-Zero Scenarios*




## Transportation

The transportation sector in the PATHWAYS model covers all energy demands and direct GHG emissions associated with on-road passenger and commercial vehicles as well as non-road transportation like

aviation, maritime shipping, and rail. On-road vehicles dominate transportation emissions in North Carolina, accounting for over 90% of emissions from the sector in 2018. Because on-road vehicles are such a large source of GHG emissions, reducing fossil fuel combustion in vehicles through ZEV adoption, reducing vehicle miles travelled (VMT), and blending in decarbonized fuels for heavy-duty and off-road vehicles is critical to achieving significant GHG reductions in North Carolina.

***Table 3.*** *Transportation Sector Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| Fuel Economy Standards | Fleet-wide average annual fuel efficiency improvements of 8% for model years 2024-2025 and 10% for model year 2026[26] | | | |
| VMT Reductions | None | 1.2% reduction in LDV VMT by 2040[27] | | |
| LDV ZEV Sales | 11% by 2030,<br>35% by 2050[28] | 72% by 2030,<br>100% by 2035 | 34% by 2030,<br>100% by 2045 | |
| MHDV ZEV Sales | 11% by 2030,<br>29% by 2050[29] | 32% by 2030,<br>100% by 2045[30]<br>(89/11 split between BEV* and HFCV**)[31] | 32% by 2030,<br>100% by 204530<br>(77/23 split between BEV and HFCV)31 | |
| Bus ZEV Sales | 5% by 2050 | 100% by 2030[32] | | |
| Renewable Diesel | None | None | 75% blend by 2050 | None |

** Battery Electric Vehicles*
*** Hydrogen Fuel-Cell Vehicles*

All Net-Zero Scenarios assume a critical role for smart growth, transit, and adoption of zero-emission vehicles. Table 3 shows the key assumptions for these measures by scenario. While VMT is expected to grow in the Reference Scenario, the Net-Zero Scenarios include VMT reduction measures for LDVs that help to reduce this growth. Within the PATHWAYS model, VMT reductions only directly impact final energy demand and GHG emissions from the transportation sector, but there are significant other air quality and public health benefits to VMT reduction measures, like smart growth, walkable/bikeable cities, and transit investment, that are not captured here.

[26] Improvements based on latest DOT fuel economy standards: https://www.nhtsa.gov/press-releases/usdot-announces-new-vehicle-fuel-economy-standards-model-year-2024-2026

[27] VMT reductions based on E3 estimates of statewide impacts of local measures modeled by NC DOT: https://www.ncdot.gov/initiatives-policies/environmental/climate-change/Documents/vehicle-miles-traveled-reduction-study.pdf

[28] Business-as-usual LDV EV sales based on E3 analysis of NHTSA CAFE compliance modeling: https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system

[29] Business-as-usual MHDV ZEV sales based on E3 analysis of CBO commercial vehicle incentive spending through 2031, with extrapolation through 2050: https://www.cbo.gov/system/files/2022-08/hr5376_IR_Act_8-3-22.pdf

[30] MHDV ZEV sales shares between 2024-2035 are aligned with CARB Advanced Clean Trucks requirements: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/act2019/fro2.pdf

[31] BEV/HFCV split for High Electrification and High Decarbonized Fuels/High Carbon Storage scenarios based on Advanced Electricity and Advanced H2 cases, respectively, from NREL MHDV cost-effectiveness study: https://www.nrel.gov/docs/fy22osti/82081.pdf

[32] Bus ZEV sales based on assumptions used for NREL MHDV cost-effectiveness study

ZEV adoption for all vehicle classes is a key driver of emissions reductions in all scenarios. While ZEV sales are expected to steadily increase over time in the Reference Scenario, they ramp up dramatically by the early 2030s and reach 100% ZEV sales for all vehicle classes by 2045 in all net-zero scenarios. Figure 25 and Figure 26 show the annual sales share and resulting on-road vehicle stocks for LDVs and MHDVs, respectively, in all scenarios. For remaining diesel MHDVs on the road in 2050, the High Decarbonized Fuels Scenario has a 75% blend of renewable diesel to further mitigate emissions.

***Figure 25.*** *LDV Annual Sales Share and Stocks by Scenario*

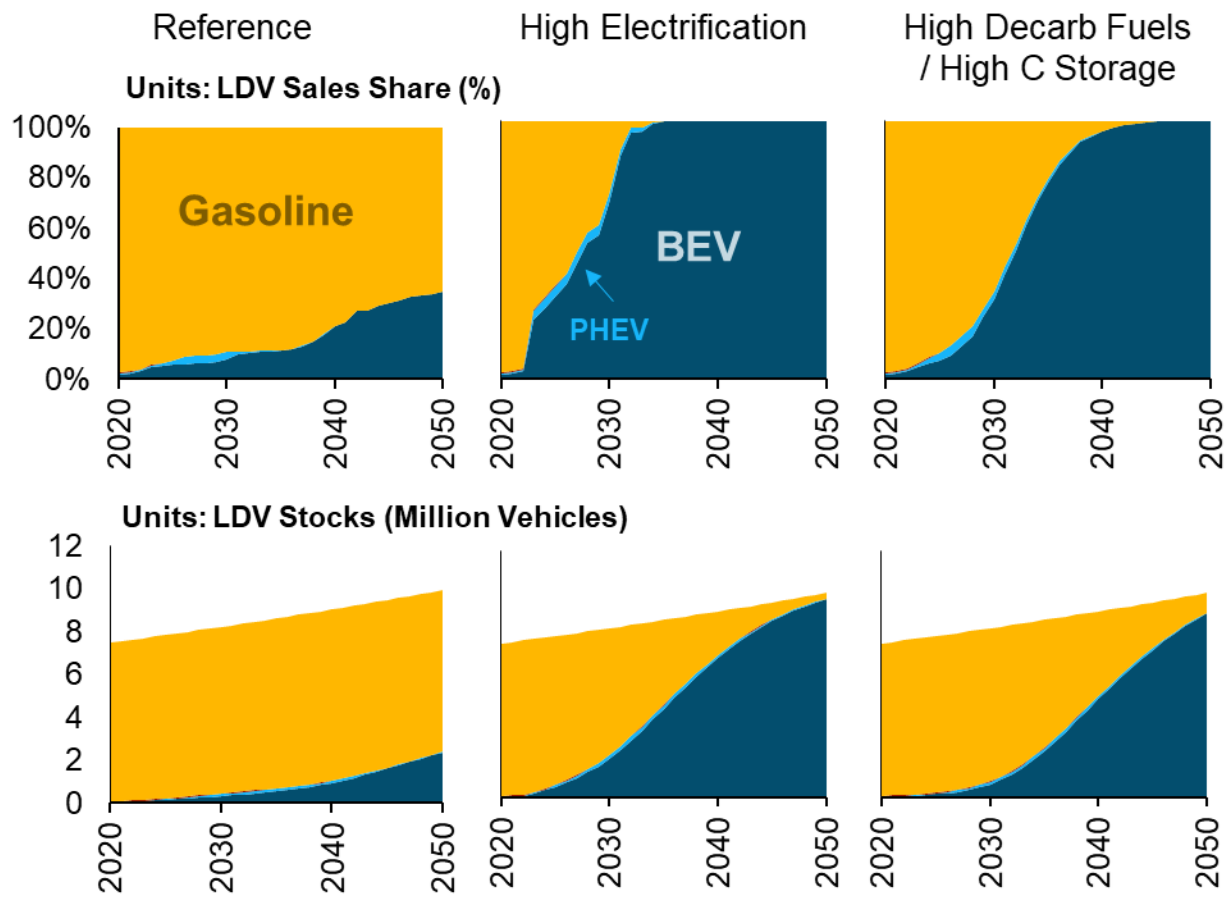
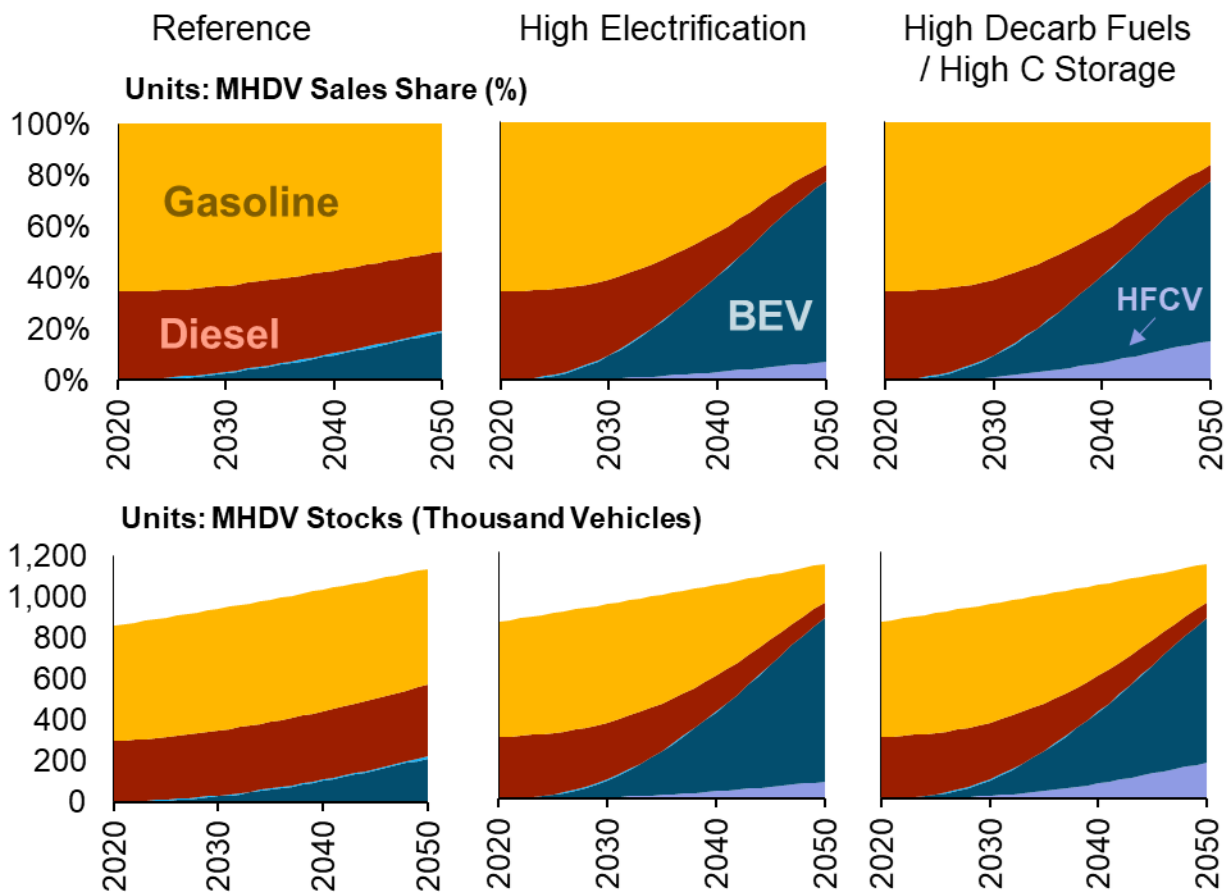


***Figure 26.*** *Medium-Duty and Heavy-Duty Vehicles Annual Sales Share and Stocks by Scenario (includes buses)*



## Buildings

The buildings sector in the PATHWAYS model covers all energy demands and direct GHG emissions associated with residential and commercial buildings. It is important to note that while the buildings sector is the largest source of electricity demand in North Carolina, emissions associated with generating this electricity are not captured in the buildings sector but in the electricity generation sector. The buildings sector in PATHWAYS only accounts for direct GHG emissions in buildings from on-site combustion of fuels for end-uses like space heating or cooking. Of these end-uses, space and water heating account for around 50% of direct GHG emissions from buildings. Relative to many other states with net-zero emissions targets, North Carolina already has a high penetration of electrified devices for space and water heating. Decarbonizing the remaining fossil fuel consumption for these and other end-uses and improving the efficiency of building envelopes and appliances are both important to achieving the State's GHG targets.

***Table 4.*** *Building Sector Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| Building Shell Improvements | All new construction built to 2015 IECC with amendments | All new construction built to 2021 IECC, one-third of existing residential buildings have shell retrofits by 2040[33] | | |
| Appliance Efficiency | Business-as-usual sales | All new appliances sold are high efficiency models by 2030 | | |
| Electrification | Heat pump sales share increases by 9%[34] | All-electric new construction by 2030, 100% sales of electrified devices for all end-uses by 2040 | All-electric new construction by 2030, 100% sales of electrified devices for all end-uses by 2045, with some sales of hybrid heat pumps for homes that have existing gas furnaces | |
| Renewable Natural Gas | None | None | 17% blend by 2050 | None |

The buildings sector in the PATHWAYS model covers all energy demands and direct GHG emissions associated with residential and commercial buildings. It is important to note that while the buildings sector is the largest source of electricity demand in North Carolina, emissions associated with generating this electricity are not captured in the buildings sector but in the electricity generation sector. The buildings sector in PATHWAYS only accounts for direct GHG emissions in buildings from on-site combustion of fuels for end-uses like space heating or cooking. Of these end-uses, space and water heating account for around 50% of direct GHG emissions from buildings. Relative to many other states with net-zero emissions targets,

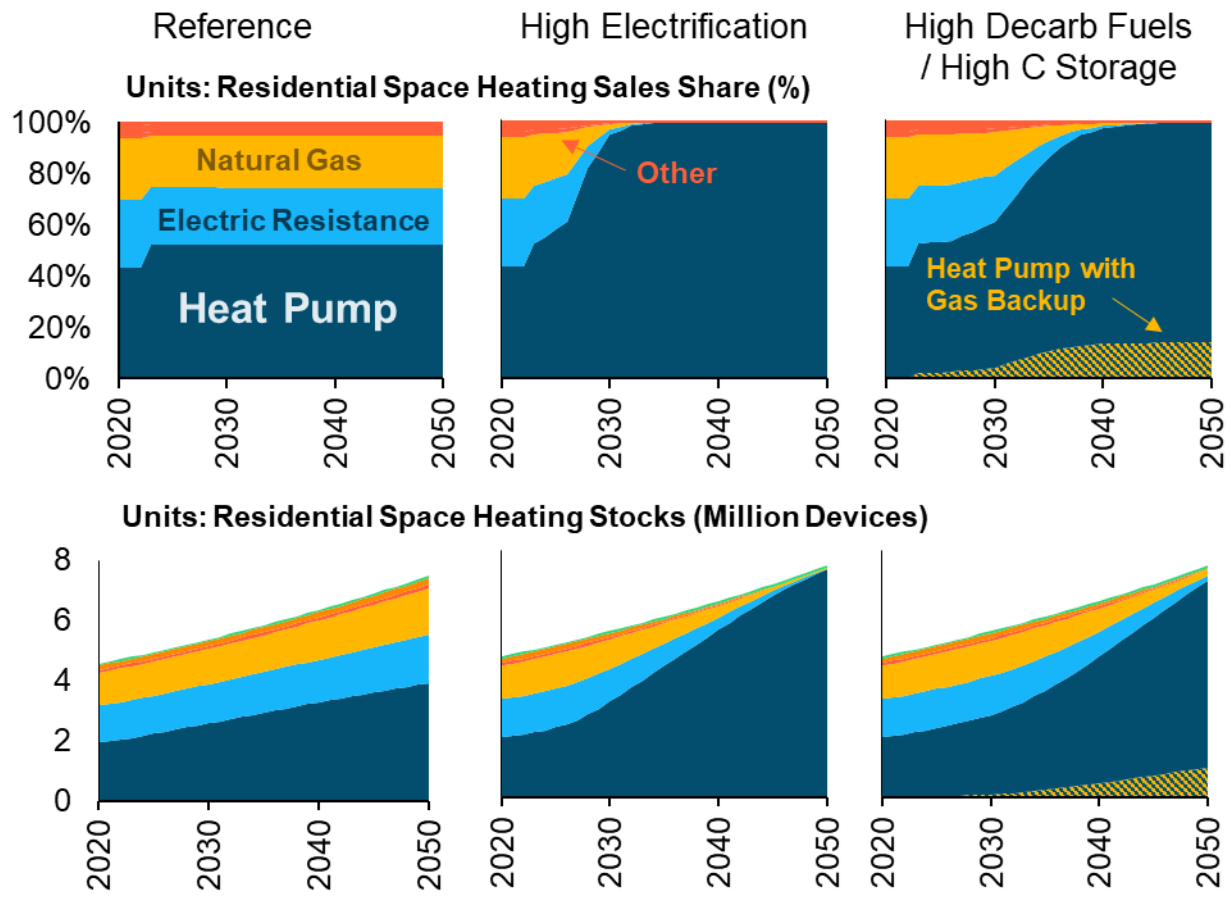
[33] Building shell retrofit penetration and efficiency benefits based on E3 analysis of expanded weatherization program modeled by ACEEE for North Carolina: https://www.aceee.org/sites/default/files/pdfs/u2007.pdf

[34] Based on internal E3 analysis of federal residential heat pump incentives made available under the IRA and their potential impact on heat pump adoption

North Carolina already has a high penetration of electrified devices for space and water heating. Decarbonizing the remaining fossil fuel consumption for these and other end-uses and improving the efficiency of building envelopes and appliances are both important to achieving the State's GHG targets.

Table 4 shows the building sector assumptions by scenario. In the Reference Scenario: existing building codes are assumed to hold constant for all new construction, appliance efficiency improvements are based on projections from the EIA Annual Energy Outlook, and there is a small increase in heat pump sales for space heating based on federal incentives. All three net-zero scenarios assume the latest International Energy Conservation Code (IECC) building codes are adopted for new construction in addition to a significant expansion of weatherization for existing buildings, all-electric new construction starting in 2030, and a transition to 100% sales of electrified devices for all end-uses by at least 2045. The High Decarbonized Fuels Scenario also includes a 17% blend of renewable natural gas by 2050, but this is not required in the other net-zero scenarios. Figure 27 shows the transition to electrified devices for residential space heating, showing the annual sales share and resulting annual building stocks for all scenarios.

***Figure 27.*** *Residential Space Heating Annual Sales Share and Stocks by Scenario*



## Industry

The industrial sector in the PATHWAYS model covers all energy demands and direct GHG emissions associated with fuel combustion for manufacturing, agriculture, construction, and mining. Manufacturing is the largest source of industrial emissions in North Carolina, accounting for 78% of the sector total in 2018. Most GHG emissions from manufacturing are a result of natural gas combustion for process heating or boilers. Outside of manufacturing, the remaining industrial sector GHG emissions are largely from gasoline and diesel use for equipment and off-road vehicles in agriculture, construction, and mining. In 2018, the total amount of GHG emissions from industrial fuel combustion in North Carolina was roughly equivalent to direct GHG emissions from buildings in the state. However, because of the highly diverse nature of energy consumption across industrial facilities and processes, the path to decarbonization for the industrial sector is more complex and varied than that for the buildings sector.

***Table 5.*** *Industrial Sector Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| **Energy Efficiency** | None | 16% reduction in manufacturing energy demand through efficiency by 2050[35] | | |
| **Natural Gas Electrification** | None | 29% of natural gas demand electrified by 2050[36] | 7% of natural gas demand electrified by 205036 | |
| **Liquid Fuels Electrification** | None | 50% of industrial gasoline and diesel demand electrified by 2050 | None | |
| **Hydrogen Fuel-Switching** | None | 5% of natural gas and 100% of coal use converted to hydrogen combustion by 2050 | 20% of natural gas and 100% of coal use converted to hydrogen combustion by 2050 | |
| **Renewable Fuels** | None | None | 75% renewable diesel blend and 17% renewable natural gas blend by 2050 | None |

The industrial sector in the PATHWAYS model covers all energy demands and direct GHG emissions associated with fuel combustion for manufacturing, agriculture, construction, and mining. Manufacturing is the largest source of industrial emissions in North Carolina, accounting for 78% of the sector total in 2018. Most GHG emissions from manufacturing are a result of natural gas combustion for process heating or boilers. Outside of manufacturing, the remaining industrial sector GHG emissions are largely from gasoline and diesel use for equipment and off-road vehicles in agriculture, construction, and mining. In

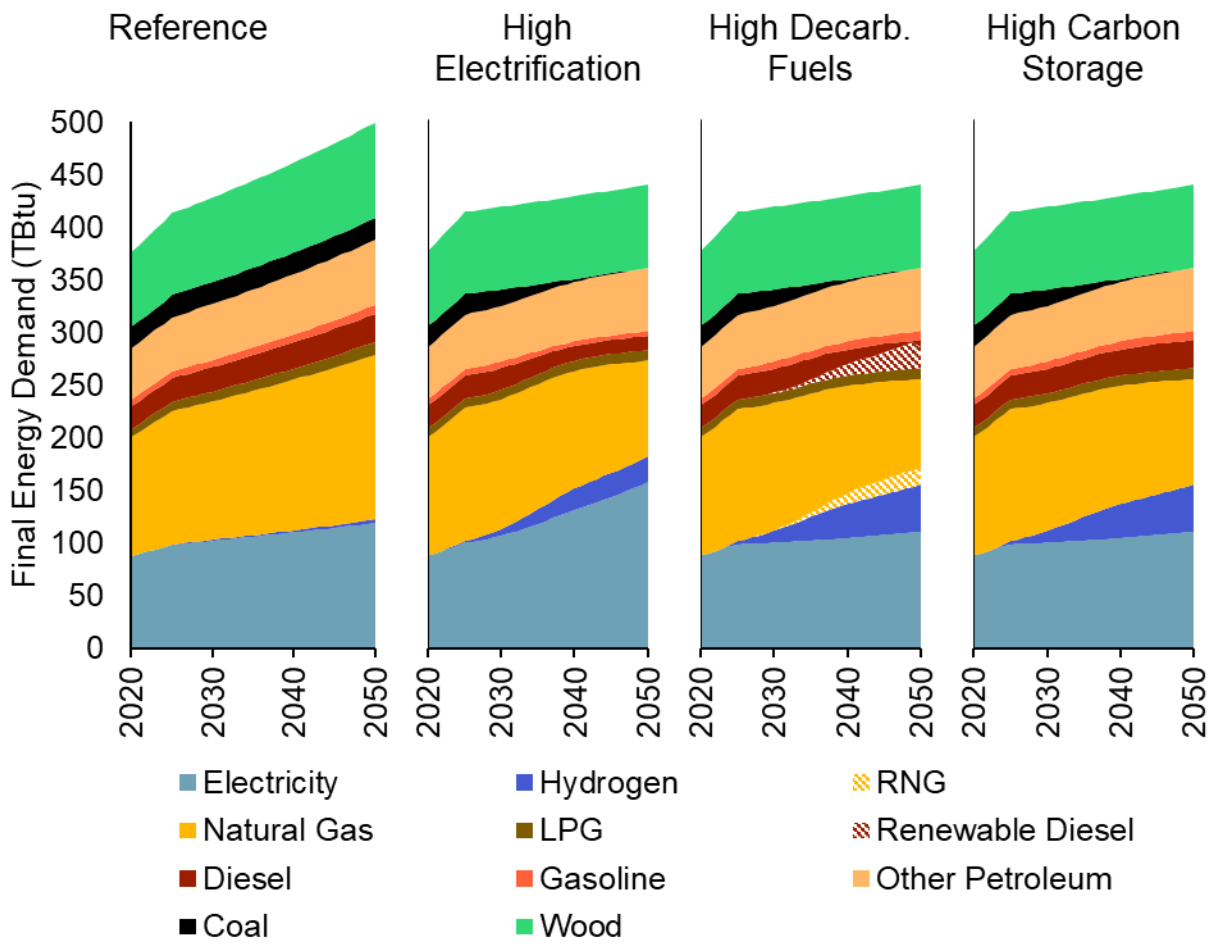
[35] Manufacturing efficiency improvements based on expanding existing practices modeled in ACEEE Halfway There report: https://www.aceee.org/sites/default/files/publications/researchreports/u1907.pdf

[36] Natural gas electrification assumptions for High Electrification and High Decarbonized Fuels/High Carbon Storage scenarios based on High Electrification and Medium Electrification scenarios modeled in NREL Electrification Futures Study: https://www.nrel.gov/docs/fy18osti/71500.pdf

2018, the total amount of GHG emissions from industrial fuel combustion in North Carolina was roughly equivalent to direct GHG emissions from buildings in the state. However, because of the highly diverse nature of energy consumption across industrial facilities and processes, the path to decarbonization for the industrial sector is more complex and varied than that for the buildings sector.

Table 5 shows the assumptions by scenario for the industrial sector. The three Net-Zero Scenarios include a mix of energy efficiency, electrification, and low-carbon fuels to achieve emission reductions from industrial fuel use. The High Electrification Scenario includes more aggressive assumptions around electrification for natural gas and liquid petroleum fuels, while the High Decarbonized Fuels and High Carbon Storage Scenarios assume more aggressive assumptions for hydrogen fuel-switching. Finally, the High Decarbonized Fuels Scenario also includes the same blends of renewable diesel and renewable natural gas that are used for the transportation and building sectors. Figure 28 shows how final energy demand changes over time in the industrial sector as a response to these measures.

***Figure 28.*** *Final Energy Demand by Fuel for the Industrial Sector by Scenario*



## Electricity Generation

The electricity generation sector accounts for all GHG emissions associated with fossil fuel combustion in the production of electricity. While demand for electricity is accounted for in the various demand sectors (buildings, transportation, industry), the emissions are accounted for in the electricity generation sector. As in the 2022 North Carolina GHG Inventory, this includes both emissions from in-State generating facilities and emissions from out-of-State generating facilities that produce electricity consumed in North Carolina.

***Table 6.*** *Electricity Sector Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| GHG Emissions from Facilities Subject to HB 951 | 70% reduction in total emissions by 2030[37], 100% reduction by 2050 | | | |
| GHG Emissions from Other Facilities | 39% reduction in emissions intensity by 203037, held constant through 2050 | 39% reduction in emissions intensity by 203037, 100% reduction by 2050 | | 39% reduction in emissions intensity by 203037, 70% reduction by 2050[38] |

Electricity demand increases in all scenarios due to population and economic growth in addition to the electrification of buildings, transportation, and industrial fuel use. **Figure 29** shows this increase over time in all scenarios. The increase in building loads in the Net-Zero Scenarios are largely offset by energy efficiency measures and the embedded efficiency of replacing electric resistance devices with heat pumps. However, there is significant growth in load from transportation electrification.

This analysis did not create new detailed modeling for the electricity sector such as capacity expansion or hourly dispatch modeling given ongoing work with the Carbon Plan, but each scenario modeled reductions in GHG emissions from the electricity sector and annual change in electricity demand. Table 6 shows these assumptions by sector. Between 2018 and 2030, these reductions are consistent with the assumptions made by NCDEQ in their modeling for the 2022 North Carolina GHG Inventory. For facilities subject to **HB 951** (facilities either owned by Duke Energy or from which Duke Energy purchased power), total emissions are assumed to decline to 70% below 2005 levels. For **non-HB 951** facilities, a 39% reduction in the emissions intensity of generation by 2030 is included for all scenarios, again aligning with modeling for the *2022 Inventory*. By 2050, we assume a 100% reduction in emissions from **HB 951** facilities (the bill allows for 5% of the 2050 reductions to come from offsets, but this was not directly modeled in our analysis). For **non-HB 951** facilities, their emissions intensity is assumed to hold constant in the Reference Scenario, but that declines over time in the Net-Zero Scenarios (reaching a 70% reduction in the High Carbon Storage

[37] Reductions in GHG emissions from electricity generation through 2030 are based on DEQ modeling of the electricity sector from the 2022 North Carolina GHG Inventory: https://deq.nc.gov/media/27070/download?attachment

[38] Reductions in GHG emissions intensity for electricity through 2050 based on EIA Annual Energy Outlook Reference Case results for SERC Reliability Corporation region: https://www.eia.gov/outlooks/aeo/tables_ref.php

Scenario and a 100% reduction in remaining two Net-Zero Scenarios). Figure 30 shows the resulting annual GHG emissions from electricity generation in each scenario.

***Figure 29.*** *Annual Electricity Demand by Sector and Scenario*

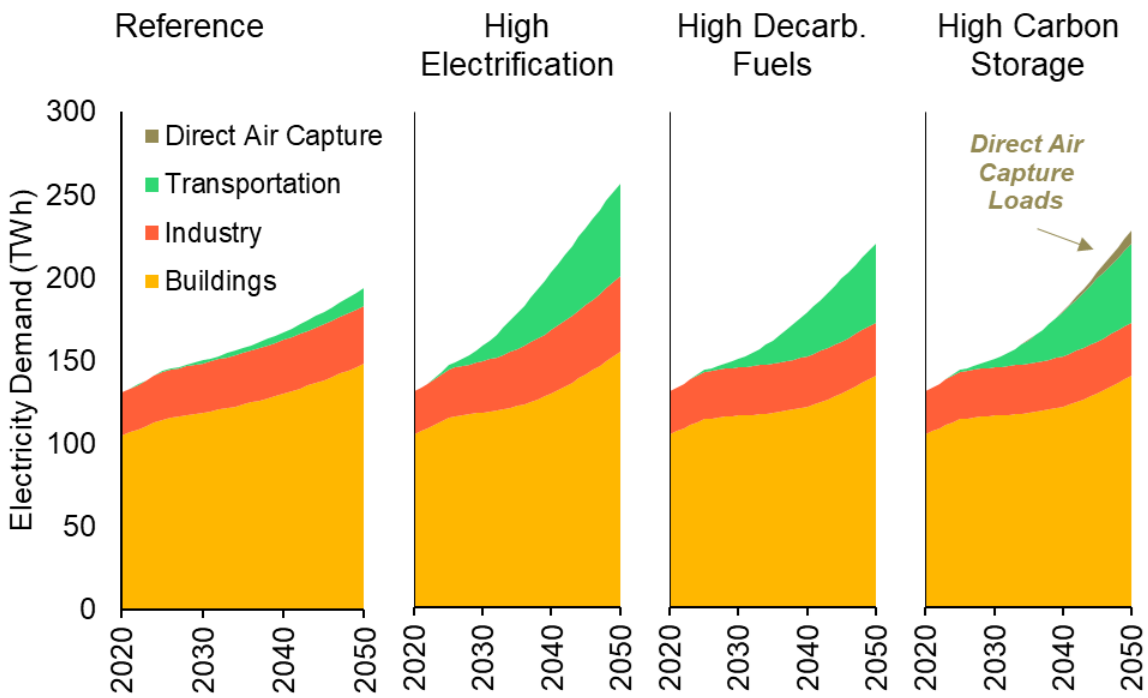
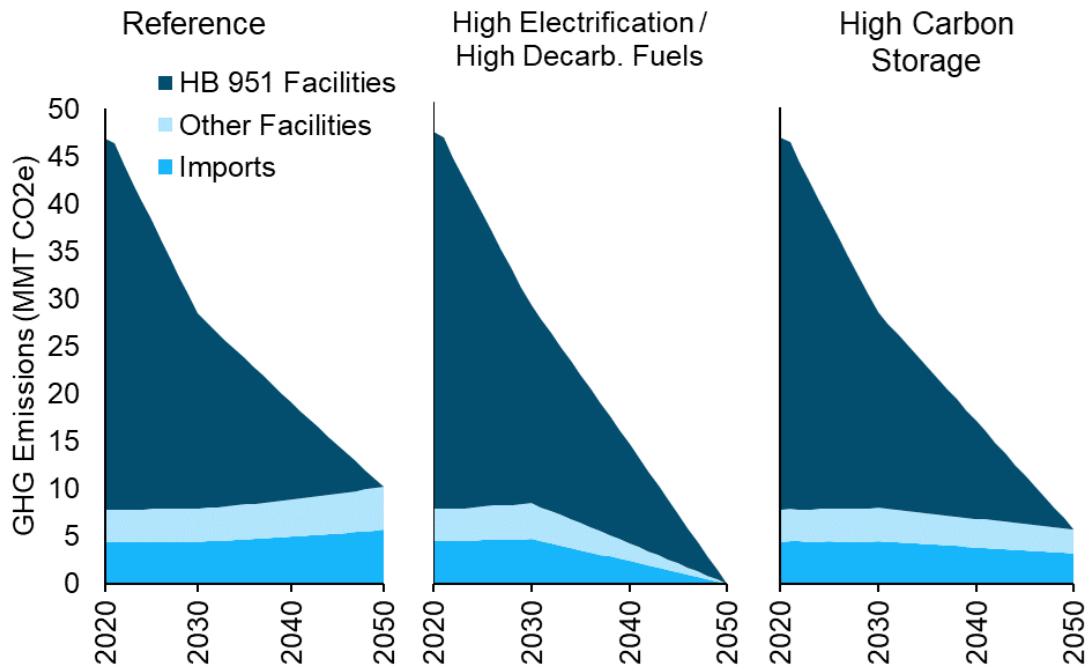



***Figure 30.*** *Annual GHG Emissions by Source in the Electricity Sector by Scenario*



## Non-Energy and Non-Combustion Sectors

In addition to the energy demand sectors (buildings, transportation, industry) and the electricity generation sector, there are four non-energy, non-combustion sectors where GHG emissions are produced from human activities other than fossil fuel combustion:

1. **Agriculture** – Includes methane and nitrous oxide emissions from agricultural sources like animal manure, enteric fermentation, and soil fertilizer. In North Carolina, manure management is the largest source of emissions, accounting for 58% of agriculture sector emissions.
2. **Industrial Processes and Product Uses** – Includes GHG emissions generated and emitted as the byproducts of non-energy-related industrial processes. Of these, by far the largest source is hydrofluorocarbons (HFCs) and perfluorochemicals (PFCs) – chemicals that are used most commonly in refrigeration and air conditioning units. Use of these chemicals accounts for 87% of the emissions from industrial processes in North Carolina.
3. **Oil and Gas Systems –** Includes fugitive methane and carbon dioxide emissions from the production, processing, and transportation of oil and natural gas. Because North Carolina has no significant oil and gas production or processing, this is a relatively small source of GHG emissions in the State, with all of the emissions in the sector coming from methane leakage in the natural gas distribution system.
4. **Waste –** Includes methane emissions from landfills and wastewater treatment plants. Around 80% of total waste emissions are from landfill methane, with the remainder coming from wastewater treatment.

***Table 7.*** *Non-Energy, Non-Combustion Sectors Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| Agriculture | None | 59% reduction in livestock methane and N2O emissions by 2050, relative to Reference[39] | | |
| Industrial Processes & Product Uses | 87% reduction in HFC emissions by 2050, relative to 2018[40] | | | |
| Oil & Gas Systems | None | 47% reduction in fugitive emissions by 2050, relative to Reference39 | | |
| Waste | None | 11% reduction in landfill methane emissions by 2050, relative to Reference39 | | |

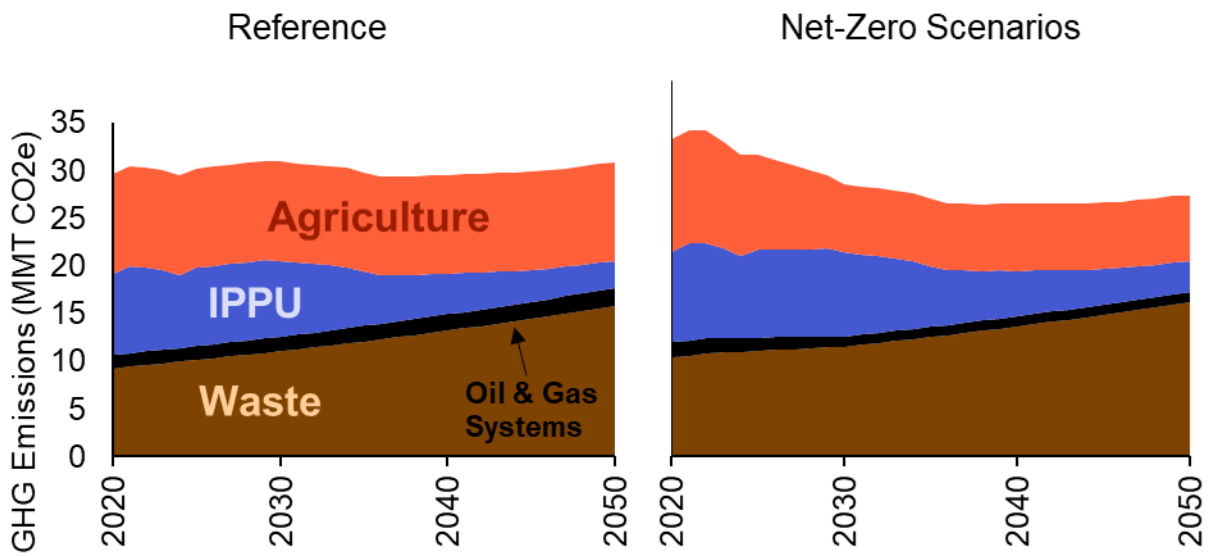
Non-energy, non-combustion sectors including agriculture, industrial processes and product use (IPPU), oil and gas systems, and waste activities contribute to emissions of short-lived climate pollutants (SLCPs) including methane and hydrofluorocarbons (HFCs), which have an outsized impact on the climate over a

[39] Mitigation potential for all agriculture, oil and gas systems, and waste sectors comes from EPA State-level analysis of non-$CO_2$ GHG emissions mitigation potential, with a cost screening applied to only include measures below \$100/$tCO_2e$: https://cfpub.epa.gov/ghgdata/nonco2/usreports/

[40] Reduction in HFC emissions based on regulatory impact analysis for EPA HFC phasedown program: https://www.epa.gov/system/files/documents/2021-09/ria-w-works-cited-for-docket.pdf

shorter time horizon. SLCP emissions are challenging to mitigate compared to energy sector emissions. Apart from industrial processes, where federal policy on HFCs is expected to drive deep reductions, the EPA estimates that only 28% of non-energy, non-combustion emissions in North Carolina are technically feasible to mitigate by 2050[39]. The mitigation measures implemented in the Net-Zero Scenarios rely on the same EPA analysis of mitigation potential but use a screening that excludes the most expensive measures costing over $100/tCO$_2$e. For agriculture, the EPA analysis estimates the largest reductions come from anaerobic digestion[41] and capture of methane from livestock manure, but these reductions could also be achieved through designated environmentally superior technologies or other activity changes[42].

***Figure 31.*** *Annual GHG Emissions For Non-Energy, Non-Combustion Sectors for Reference and Net-Zero Scenarios*




[41] Anaerobic digestion is a process through which bacteria break down organic matter—such as animal manure, wastewater biosolids, and food wastes—in the absence of oxygen

[42] As described in Williams, 2009, environmentally superior technologies are alternatives to anaerobic lagoon treatment and land application of swine manure that are required to meet performance standards for impacts of animal waste to surface and groundwater, emissions of ammonia and odor, release of disease-transmitting pathogens, and heavy metal contamination of soil and groundwater. (https://pubmed.ncbi.nlm.nih.gov/19286371/). One example of these technologies, a nitrification-denitrification system at a hog farm in Clinton, NC showed a 99% reduction in methane emissions relative to a conventional anaerobic lagoon system over a 15-month observation period, in addition to a significant reduction in air and water pollutants: https://www.usda.gov/sites/default/documentsfiles//GHG_Mitigation_Options.pdf

## Natural and Working Lands

Natural and working lands (NWL), sometimes referred to as land-use, land-use change, and forestry (LULUCF), account for natural carbon fluxes in North Carolina. The State has a large negative annual carbon flux due to carbon sequestered in aboveground biomass (mostly forests) and in wood products. These natural sinks help to offset remaining gross emissions in all scenarios, with deployment of negative emissions technologies only required in one Net-Zero Scenario. Figure 32 shows that despite a slight decline due to loss of forest acreage and sea-level rise, natural carbon sinks in North Carolina remain large through 2050. In the High Carbon Storage Scenario, these are supplemented with additional natural carbon sequestration and negative emissions technologies. While North Carolina's natural carbon sinks are critical to achieving net-zero, future carbon fluxes from natural systems are relatively less certain than the emissions reductions achieved through direct decarbonization measures elsewhere in the economy.

***Table 8.*** *LULUCF and Negative Emissions Key Assumptions by Scenario*

| Category | Reference | High Electrification | High Decarbonized Fuels | High Carbon Storage |
|---|---|---|---|---|
| Natural Carbon Sinks | Existing sequestration declines slightly over time due to projected loss of forests[43] and sea-level-rise impacts[44] (~2.4 MMT CO2e reduction in net sequestration by 2050) | | | Reforestation[45] and restoration of saline tidal flows[46] leads to ~4 MMT CO2e of incremental sequestration |
| Negative Emissions Technologies | None | | | 6.6 MMT of NETs required to offset remaining gross emissions, modeled as DAC |

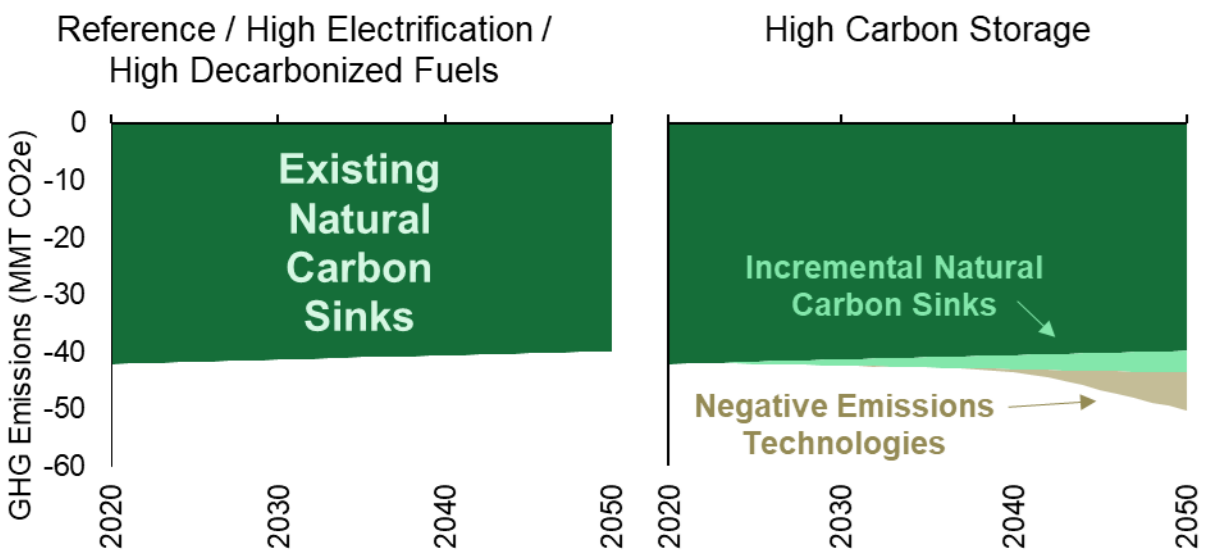
[43] Loss of carbon sinks from forest loss estimated by E3 using projected forest acreage loss from Sanchez et al., 2020: https://www.sciencedirect.com/science/article/abs/pii/S0048969720325675?via%3Dihub#f0035

[44] Loss of carbon sinks from sea-level rise estimated by E3 using changes in annual carbon flux projected for North Carolina in Warnell et al., 2022: https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000044

[45] Incremental carbon sequestration from reforestation estimated in the 2020 North Carolina Natural and Working Lands Action Plan: https://deq.nc.gov/media/17743/download

[46] Mitigation impacts of restoring saline tidal flows estimated by E3 using data from Warnell et al, 2022.

***Figure 32**. Annual Emissions Sinks by Scenario*

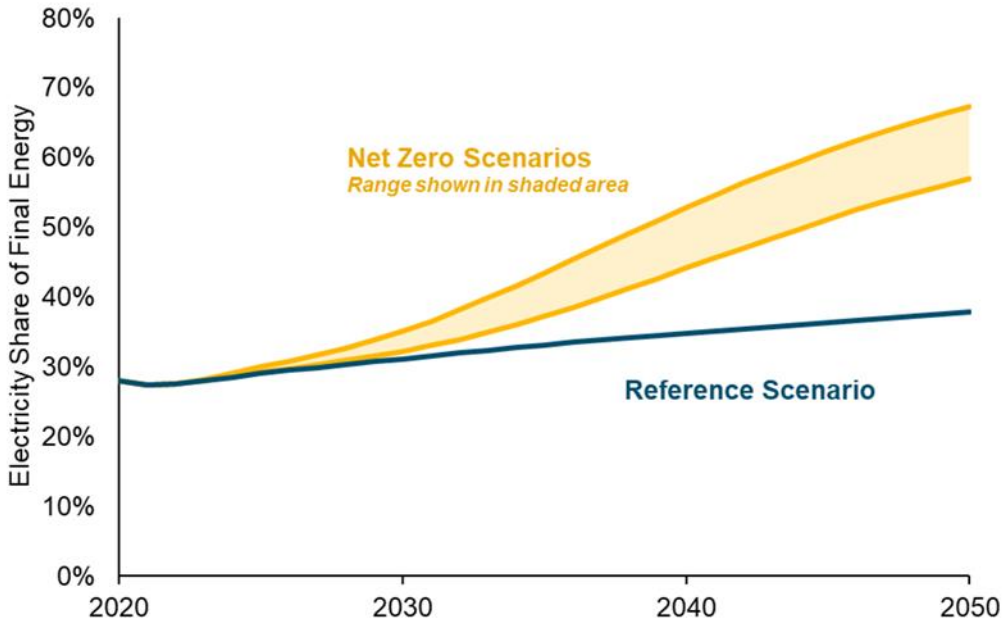


## Key Findings

The Pathways Analysis shows that there are multiple roads to meeting North Carolina's 2030 and 2050 climate targets. Regardless of the different mix of mitigation technologies each pathway relies on, there are commonalities across all scenarios. These commonalities represent near-term opportunities for "no-regret" actions in North Carolina, as seen in the findings below.

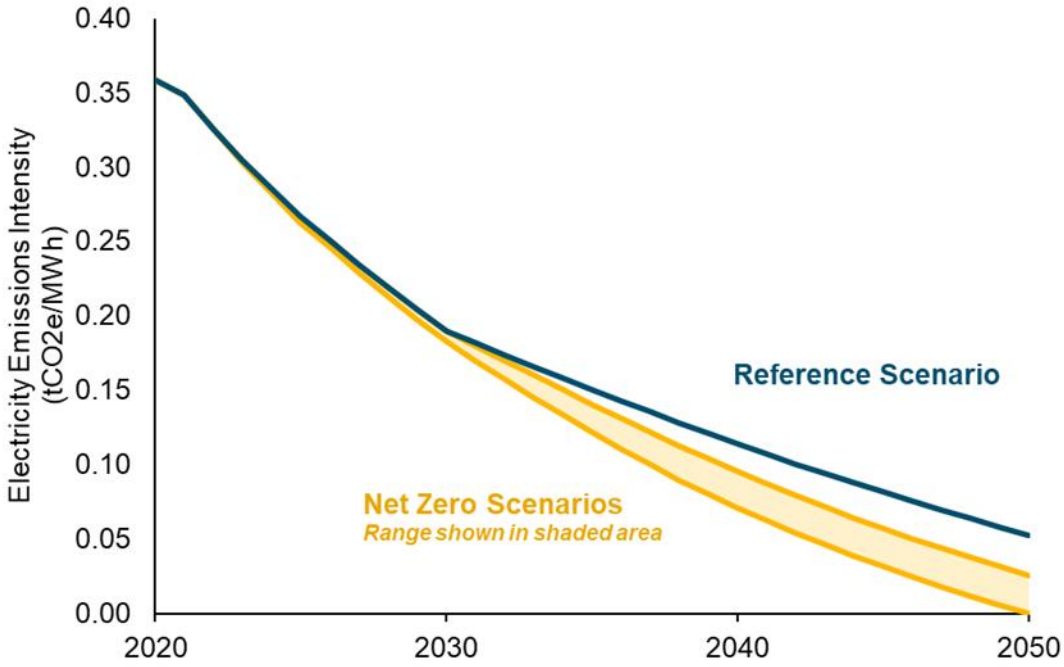
**Finding #1: Accelerate a transition to ZEVs and electric heat pumps in buildings.** All Net-Zero Scenarios: 1) Feature a rapid ramp-up of ZEV sales in the next decade, 2) Achieve 100% of electric passenger vehicle and electric bus sales in the 2030s, and 3) Reach 80-100% of electric and hydrogen fuel-cell MHD vehicle sales in the 2040s. Similarly in buildings, these scenarios require electric appliance sales to reach 80-100% by 2040. As a result of the rapid transition, electricity becomes the foremost fuel powering the economy, meeting 57-67% of all energy demand increasing from about 30% today (see Figure 33).

***Figure 33.*** *Electricity Share of Final Energy for Reference and Net-Zero Scenarios*



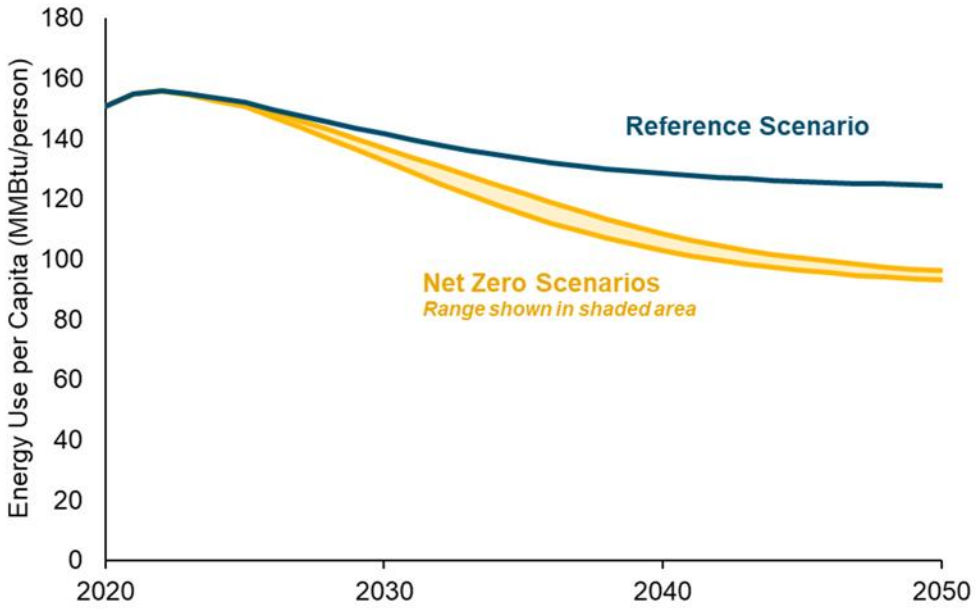
**Finding #2: Rapidly decarbonize electricity generation by scaling up renewable electricity sources and battery storage.** Across all net-zero scenarios, rapid transition to electric vehicles and heat pumps makes electricity the major source of final energy, increasing today's annual electricity demands by 70-100% by 2050. To achieve economy-wide decarbonization, the rising electricity demands must be powered by a rapidly increasing share of zero-carbon electricity generation that goes even beyond the HB 951 requirements. Even with total annual electricity demand continuing to increase, the emissions intensity of North Carolina's electricity generation decreases by 93-100% by 2050 in order to achieve net-zero goals (see Figure 35).

***Figure 34**. Electricity Emissions Intensity for Reference and Net-Zero Scenarios*



**Finding #3: Encourage high levels of energy efficiency, such as adoption of efficient appliances and vehicles, improvement of building shells, and reduction in vehicle miles traveled.** All Net-Zero Scenarios feature the same high level of these energy efficiency measures. In addition, the rapid electrification of building and transportation sectors greatly reduce energy demands for the same services since electric vehicles and heat pumps can be two-to-four times as efficient as current fossil-powered options[47]. As a result of high levels of energy efficiency, conservation and electrification, energy use per capita may decrease by ~45% by 2050 while meeting the same services (see Figure 35).

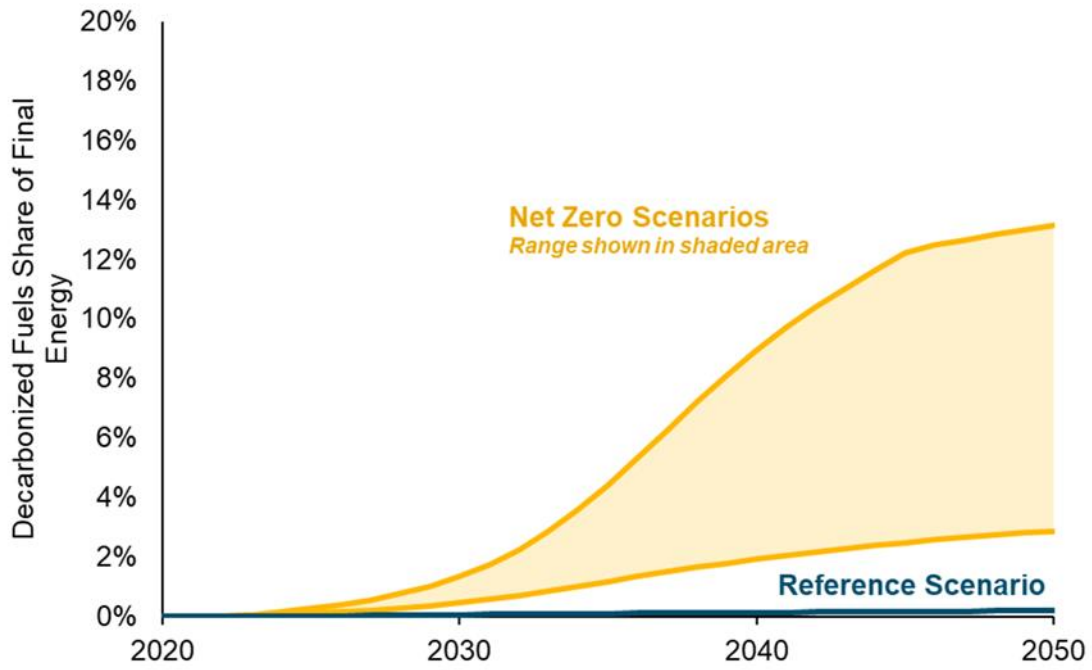
***Figure 35**. Energy Use Per Capita for the Reference and Net-Zero Scenarios*




[47] Source: https://rmi.org/its-time-to-incentivize-residential-heat-pumps/

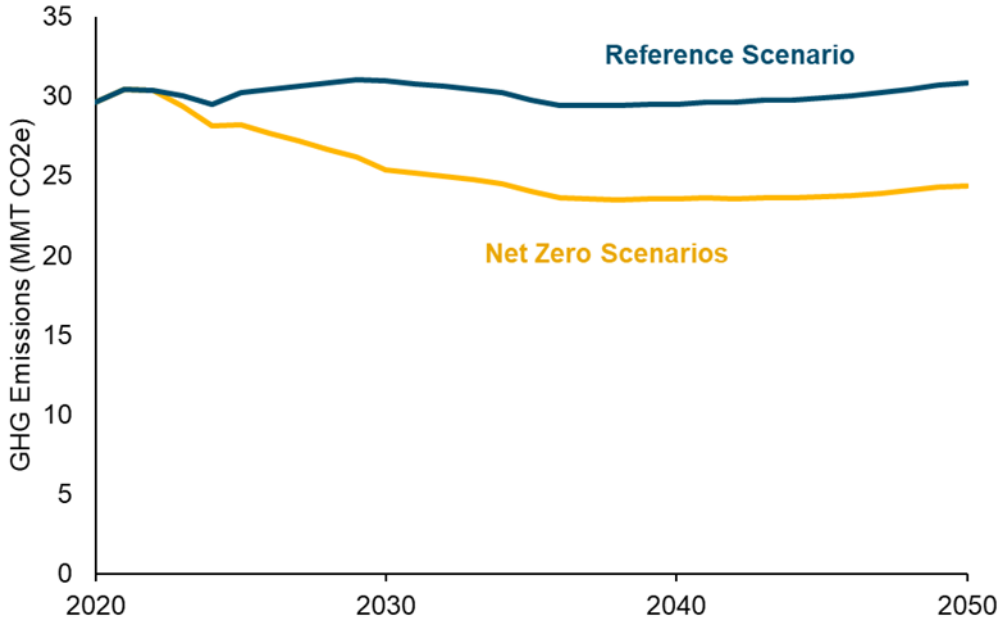
**Finding #4: Support commercialization of decarbonized fuels, at a minimum to green hydrogen for industry and large trucks, and explore pilots for advanced biofuels using sustainable biomass feedstocks.** Across all Net-Zero Scenarios, hydrogen produced through electrolysis using zero-carbon renewable electricity (green hydrogen) for industry and heavy-duty hydrogen fuel-cell vehicles become the main source of decarbonized fuels. The High Decarbonized Fuels Scenario highlights the potential role of advanced biodiesel to further decarbonize heavy-duty transportation and industry. Overall, decarbonized fuels serve a critical but targeted role for hard-to-electrify sectors, reaching 3-13% of energy demand (see Figure 36). At the low end of this range, hydrogen accounts for 3% of final energy demand by 2050 in the High Electrification Scenario. At the high end of this range, renewable natural gas, renewable diesel, and hydrogen account for 1%, 4%, and 8% of final energy demand, respectively, by 2050 in the High Decarbonized Fuel scenario. The use of decarbonized fuels will need to consider local environmental and environmental justice impacts.

***Figure 36.*** *Decarbonized Fuels Share of Final Energy Demand in Reference and Net-Zero Scenarios*



**Finding #5: Reduce non-energy GHG emissions from industry, agriculture, waste, and oil and gas systems.** These sectors are some of the most challenging to mitigate at reasonable costs[48]. However, results from all net-zero scenarios show that the non-energy sectors can achieve 12% reductions in 2050 compared to the trajectory with existing policy and trends (see Figure 37).

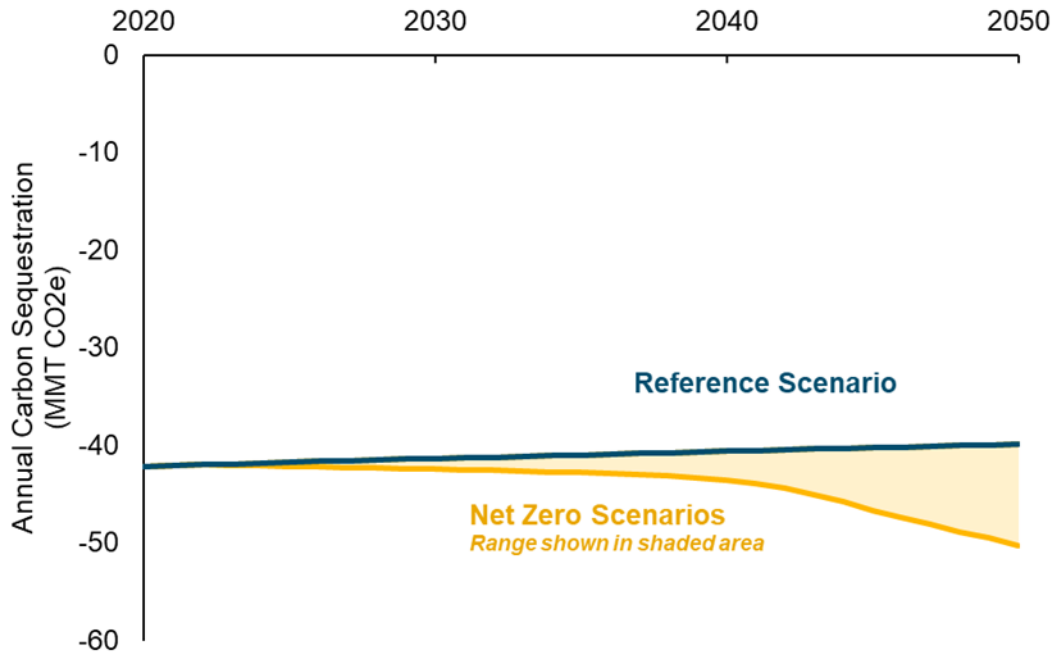
***Figure 37.*** *Non-Energy GHG Emissions*




[48] Apart from the industrial processes sector, where federal policy on HFCs is expected to drive deep reductions that are included in the Reference Scenario, the EPA estimates that only 28% of non-energy, non-combustion emissions in North Carolina are technically feasible to mitigate by 2050 regardless of cost: https://cfpub.epa.gov/ghgdata/nonco2/. A $100/tCO$_2$e screening was applied for this analysis, bringing the total mitigation potential to ~21% lower than the Reference Scenario emissions in 2050.

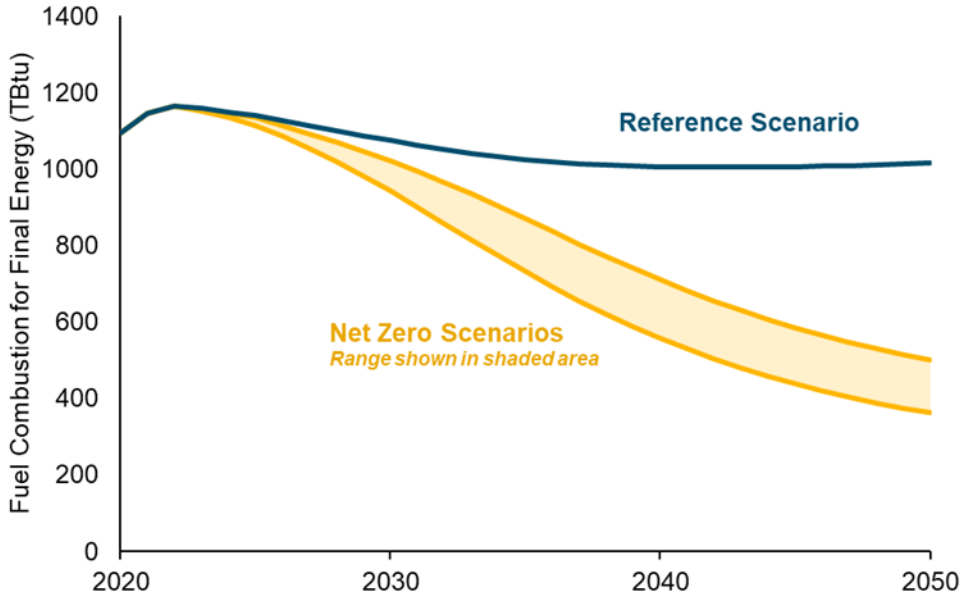
**Finding #6: Prioritize sustainable management of NWL to enhance the critical role of carbon sequestration in helping achieve net-zero emissions.** North Carolina's natural carbon sink plays a critical role in offsetting GHG emissions from combustion and other activities. The High Carbon Storage Scenario highlights the potential of enhancing natural carbon sinks through land conservation, land management, and forest restoration, which lead to an additional 3.8 MMT of sequestration relative to the Reference Scenario and negative emissions technologies, which contribute an additional 6.6 MMT of annual sequestration in 2050 (see Figure 38).

***Figure 38.*** *GHG Emissions Sequestration from Natural and Working Lands and Negative Emissions Technologies (e.g., DAC)*



**Finding #7: Reducing fuel combustion while decarbonizing the economy will create co-benefits for air quality improvement**, especially in disadvantaged communities that have been historically disproportionately impacted by vehicle emissions. By 2050, across all Net-Zero Scenarios when compared to today, petroleum combustion is reduced ~80%, natural gas combustion is reduced 50-70%, and coal combustion in industry is reduced by 100% (as shown in Figure 39).

***Figure 39.*** *Total Fuel Combustion for Final Energy Demand in the Reference and Net-Zero Scenarios (Excludes Fuel Combustion for Electricity Generation)*



# Roadmap to Net Zero

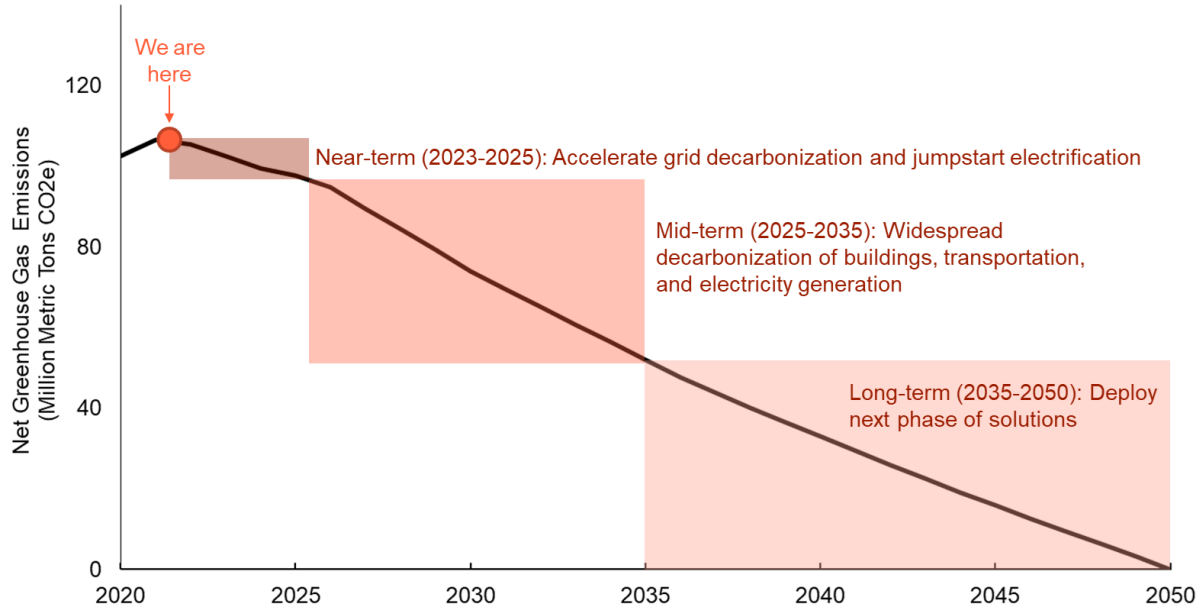
## Overview

This Pathways Analysis highlights the critical need and opportunity to transform every sector of the economy on a path to net-zero greenhouse gas (GHG) emissions by 2050. Success will require sustained, equitable and ambitious action. While there is no single path to reach the State's climate goals, all transitions to a net-zero future share the "no-regret" actions outlined in the Key Findings section. Drawing from those commonalities, **this section outlines more targeted recommendations and identifies timely opportunities for North Carolina to reduce emissions.** This Roadmap to Net Zero is by no means an exhaustive overview of decarbonization opportunities and needs across North Carolina, and can be further refined to serve local, regional, and statewide contexts. It can inform budget prioritization, program administration, and future legislative and regulatory action. Additionally, it can help direct the efforts of public-private partnerships, academic research, and the advocacy of public interest organizations.

The roadmap below separates recommendations into three phases:

1. Near-term actions that should be prioritized in the next few years
2. Mid-term actions that should be ramped up before 2035
3. Long-term actions that will be needed to achieve 2050 goals

***Figure 40.*** *North Carolina Roadmap to Net Zero*



# Near-Term (2023-2025) – Accelerate Grid Decarbonization and Jumpstart Electrification

The next three years should lay a solid foundation for clean electricity and widespread electrification. Clean electricity-powered electric vehicles and appliances are a forceful combination in reducing GHG emissions. The first phase of the roadmap should also prioritize the continued evaluation of mitigation options and impacts on North Carolina communities and lay the foundation for the midcentury transition.

## Accelerate Electric Grid Decarbonization

The electric grid is a critical lynchpin for economy-wide decarbonization and could potentially directly power between 57-67% of the economy by 2050, serving both existing and new electricity demands with zero-carbon power generation.

- The NCUC's Carbon Plan will transform the goals of HB 951 into an implementable action plan. It will be the first step toward developing a coordinated grid planning process that considers the investments needed to scale zero-carbon electricity generation while meeting new electricity demands and considering the role of distributed energy resources and grid resiliency. The Carbon Plan, adopted by the North Carolina Utilities Commission on December 30th, 2022, sets forth near-term investment in electric generation, balancing various generation types to achieve the legislatively-mandated carbon reductions. Corresponding investments will also need to be made in the transmission and distribution grids to enable clean energy generation to be transmitted to load centers, support electric vehicle charging infrastructure, and allow distributed energy resources and storage to be effectively utilized.

## Maximize Energy Efficiency and Jumpstart Electrification

The Pathways Analysis highlights the importance of continuing to maximize energy efficiency while transitioning to electric vehicles and appliances from our primarily fossil-fueled devices in use today. Electrification of buildings and transportation sectors are an effective way to increase energy efficiency since electric vehicles and heat pumps can be two-to-four times as efficient as current fossil-powered options. Over the next few years, North Carolina should prioritize the electrification of light-, medium- and heavy-duty vehicles, including building out adequate charging infrastructure. The State should also prioritize electrifying low-cost building space heating and water heating applications.

- Light-duty cars and trucks (e.g., sedans, SUVs, and small pick-up trucks) account for almost 70% of GHG emissions from North Carolina's transportation sector today and therefore are a high priority for rapid decarbonization. Adoption of zero-emission passenger vehicles should reach between 10-36% of sales by 2025, as shown across all three Net-Zero Scenarios. Since 2019, North Carolina has experienced significant increases in ZEV light-duty market share, indicating that the high levels of electric vehicle sales included in the Net-Zero Scenarios can be achieved with continued effort.[49]

[49] Microsoft Word - Transportation Electrification in the Southeast 2022 Report.docx (cleanenergy.org)

The North Carolina Clean Transportation Plan (NCCTP) will be finalized by April 2023 and includes prioritized actions to accelerate the adoption of electric vehicles in North Carolina. NCCTP implementation will be bolstered by federal investments (e.g., the Inflation Reduction Act [IRA]) to further reduce upfront cost barriers and address other market-development needs.

- **Medium- and heavy-duty (MHD) vehicles** represent another area to jumpstart electrification in the near term. Electric bus fleets in particular show promise for early deployment, given their reliable routes and the ability to charge at transit depots. Deployment of zero-emission buses in North Carolina grows rapidly in all three Net-Zero Scenarios, reaching 65% of new sales by 2025 on the way to 100% by 2030. Achieving this level of deployment could be assisted through support of group purchase programs and infrastructure funding mechanisms. **The NCCTP's fleet transition and MHD ZEV recommendations** will help to guide the State's strategy to encourage the electrification of commercial fleets. **EO 271** also directs numerous state actions supporting the equitable growth of the MHD ZEV market. Federal funding (e.g., Clean School Bus Program and the Low or No Emission Bus Grants) will also help to mobilize State-specific strategies.
- North Carolina and neighboring regions will need to **plan for and invest in a robust charging network** to ensure that electric vehicle drivers can travel reliably throughout the state. The levels of electric vehicle adoption modeled in the Net-Zero Scenarios could require between 9,000-26,000 public electric vehicle charging ports by 2025, compared to the 1,408 as of July 2022[50]. Charging investment should prioritize public access close to major transportation corridors, apartments, urban centers, and low- and moderate- income housing. Home charging will also increase electric vehicle adoption and can be encouraged through policies such as vehicle-ready building codes. The **NCCTP's infrastructure recommendations** will guide the Cooper Administration's efforts to invest in the State's electric vehicle charging network. **The North Carolina ZEV Infrastructure Needs Assessment (Needs Assessment)**, pursuant to **EO 271**, will also further guide the equitable deployment of electric vehicle charging infrastructure. North Carolina has the opportunity in the coming years to pair NCCTP and Needs Assessment priorities with significant funding. NCDOT is in the process of **investing $109 million in electric vehicle charging stations through the National Electric Vehicle Infrastructure (NEVI) Program**, which was authorized by the Bipartisan Infrastructure Law (BIL). NEVI investments can be complemented by other federal programs under the BIL and IRA.
    - **Managing the timing and location of electric vehicle charging** will be critical to balance the costs and benefits to the grid. Electric vehicle rate structures should be explored with North Carolina utilities and the Utilities Commission to shift charging to off-peak demand hours. In addition, the location of public and private charging stations should consider electric grid integration, to manage infrastructure upgrade costs associated with transmission and distribution infrastructure as well as to enhance grid resilience.

[50] Number of public charging ports per electric vehicle based on NREL *National Plug-In Electric Vehicle Infrastructure Analysis*: https://www.nrel.gov/docs/fy17osti/69031.pdf

Existing count of EV charging ports from NC DOT *North Carolina Electric Vehicle Infrastructure Deployment Plan*: https://www.ncdot.gov/initiatives-policies/environmental/climate-change/Documents/ncdot-electric-vehicle-deployment-plan.pdf

- **Reducing vehicle miles traveled (VMT)** across the State will be critical to GHG reduction in North Carolina and can cultivate other air quality and public health benefits. North Carolina needs to build on current efforts and invest in smart growth, walkable and bikeable cities, and public transit. The NCCTP will build on NCDOT's *Vehicle Miles Traveled Reduction Study* [51] to provide recommendations for cultivating a more efficient and accessible transportation system across the state.
- Reducing direct emissions in North Carolina homes and businesses will play an important role in the near term. By 2025, The modeled Net-Zero Scenarios show **replacements of existing appliances with high efficiency models, improvements of existing building shells, and adoption of highly efficient electric appliances,** such as heat pump water heaters and HVAC systems. It will be important to explore the opportunities and challenges in electrifying different kinds of buildings in North Carolina, including both new construction and retrofits. Targeting end-of-life replacements with high efficiency appliances in buildings could be a relatively low-cost way to achieve emissions reduction in the near term. The cost-effectiveness of other retrofits will depend on factors such as the age of buildings, needs for electric panel upgrades or ductwork, and the climate zone within the State. Stakeholders should also evaluate the opportunities to reduce building electrification retrofit costs through federal incentives and other resources so that solutions are available to all customers, especially low-to-moderate income households with a high energy burden.
  - **The State Energy Office is receiving over $200 million in funds through the IRA** to provide rebates to low-to-moderate income households to invest in electrification projects and complete retrofit and efficiency work.
  - **The North Carolina Building Code Council (NCBCC**) is currently considering revisions to the residential and commercial energy codes that will become effective by January 1, 2025. North Carolina's energy code has fallen behind national model codes and other states in the region, and this process presents a significant opportunity to reduce emissions while increasing energy savings, lowering utility bills, and creating new jobs. The **NCBCC is also currently reviewing potential** updates **to the State electrical code, which may present an additional opportunity to encourage building electrification.**
  - The current residential energy code includes a voluntary appendix for a High Efficiency Residential Option (HERO) Code. The Duke Energy Progress Residential New Construction Program offers incentives to builders and developers who build energy efficient single-family homes or multifamily residences that meet HERO Code targets. As part of the current building energy code updates, there may be an opportunity **to expand and strengthen the voluntary HERO code.**
  - **The North Carolina Energy Efficiency Roadmap** outlines further recommendations and strategies that should be consulted and implemented in the context of this Pathways Analysis.

## Explore Additional Opportunities for Carbon Storage And Sequestration in North Carolina's Natural and Working Lands

[51] https://www.ncdot.gov/initiatives-policies/environmental/climate-change/Documents/vehicle-miles-traveled-reduction-study.pdf

North Carolina's natural and working lands (NWL) are estimated to sequester over one quarter of the State's gross GHG emissions and are essential to communities, economies, and ecosystems. **To ensure that North Carolina is on the** right **track to achieve net zero by midcentury, the State should continue to focus on research and development of additional opportunities for carbon storage and sequestration in North Carolina's forests and soils.**

- **The 2020 North Carolina Natural and Working Lands Action plan includes a list of stakeholder recommendations to protect, restore, and enhance lands in the State** in addition to a set of transformative actions that could result in large amounts of increased carbon sequestration and ecosystem resilience (e.g., reducing flood and water quality risk)[52]. Research and development of the transformative actions should include (but not be limited to) protecting and restoring forests and wetlands in flood-prone areas, facilitating landowner participation in carbon offset and ecosystem services markets, and integrating climate adaptation and resiliency strategies into local government planning.

## Build on Pathways Findings to Ensure Steady Progress Toward an Affordable, Equitable, and Reliable Net-Zero Future

This effort has included extensive stakeholder engagement to gather input on key elements of the modeling and recommendations (see Appendix A), but more work is needed to complete a holistic vision for a net-zero future that fully integrates equity, affordability, and reliability while maximizing economic development in the state.

- **Transitioning to a net-zero clean energy economy must center environmental justice and equity in program design and implementation.** As an example, while new technologies like electric vehicles and electric heat pumps are increasingly offering a lifetime of savings, the upfront expenses can still be more than fossil-powered options and present a major adoption hurdle for low-to-moderate income households. Providing incentives and financing options to lower this cost barrier will be important to ensure the decarbonization transformation benefits all North Carolinians. This analysis has focused primarily on quantifying the GHG impacts of current policies and alternative measures, but a holistic strategy must also consider other environmental justice concerns, such as community proximity to industrial operations, fossil-fuel point sources, or trucking depots. More analysis can enhance the State's understanding of the disproportionate local impacts of fossil fuel combustion and other industrial activities and highlight opportunities for GHG mitigation measures to benefit historically underserved communities.
  - It will be important to **continue soliciting input on environmental justice considerations related to North Carolina's decarbonization vision**, with a particular focus on local issues of importance to specific communities. **EO 246** requires every cabinet agency to identify an environmental justice lead and create a Public Participation Plan. The order also while requires the Governor's Office and Cabinet agency leadership to seek further public input on future action on

[52] https://deq.nc.gov/media/17743/download

environmental justice. These venues can be used to solicit input on environmental justice concerns related to North Carolina's decarbonization efforts.

- **More detailed economic analysis will position the State to better prioritize decarbonization strategies and understand the impacts and opportunities related to jobs and workforce development.** The Department of Commerce anticipates modeling baseline and ongoing analyses of the workforce development and jobs needed to support implementation of the Carbon Plan prepared by the Utilities Commission. This effort will assist the State's design of policies and programs to meet the anticipated clean energy workforce needs. Over time, the model can also be used to reevaluate existing plans and propose alternative scenarios in response to changing technology, economic, and deployment conditions.
- **It will be important for North Carolina to establish a transparent monitoring and reporting process to achieve its GHG goals.** This Pathways Analysis will serve as an important foundation for decarbonization opportunities in North Carolina, but much can change over the next 30 years. In the last six months alone, we have seen new federal legislation and fuel price fluxes that significantly impact the outlook for key technology progress and customer cost-effectiveness. **Ongoing reporting and monitoring could build on regular updates to the State GHG Inventory** to ensure that the plan to achieve long-term decarbonization stays aligned with the latest research, technology commercialization, and deployment progress.

While sequenced after the near-term recommendations in this section, there will be opportunities that arise in the coming years to help lay the foundation for the mid- and long-term transition *(*shown in the following sections), including those related to building codes, the vision for clean trucking, and hydrogen commercialization.

## Mid-Term (2025-2035)-- Widespread Decarbonization of Buildings, Transportation, and Electricity Generation

To hit the State's 2030 goals and to be on the right track for 2050 goals, North Carolina needs to achieve widespread decarbonization of electricity generation, transportation, and buildings. Alongside this, the State must continue to prioritize solutions for short-lived climate pollutants and research new technologies that have not yet reached commercial maturity.

### Electricity Decarbonization

**By 2035, North Carolina's electricity supply will need to be mostly decarbonized,** passing through 70% reductions in $CO_2$ emissions by 2030 on a path to full carbon neutrality by 2050.

- GHG emissions from Duke Energy's electricity generation should be reduced 70% by 2030, as specified in **HB 951**. Questions remain, however, about the exact timing of new generating facilities coming online, as well as when emerging generation technologies such as small modular nuclear reactors and hydrogen generation will be viable for commercial deployment. These topics will be further deliberated through implementation of the Carbon Plan at the NCUC.

- Additional consideration should be given to decarbonization targets for all electricity generation consumed in the State, including imported electricity and in-State generation served by smaller utilities. Two of the decarbonization pathways scenarios model carbon neutrality for all electricity generation by 2050, which would help lessen the need for additional effort in other sectors.

## Transportation Decarbonization

In the transportation sector, it will be important to **replace most older vehicles with zero-emission alternatives.**

- Sales of zero-emission light-duty vehicles should approach 100% sales of ZEV vehicles by 2035.
- MHD trucks that are electric or hydrogen fuel cells continue to be commercialized and will need to reach about a third of new sales by 2030. This pace of adoption would lead to at least 60,000 ZEV trucks on the road in 2030 and up to 850,000 by 2050.
  - The implementation **EO 271** will support the transition of MHD trucks to zero-emission technologies. The order directs NCDEQ to work with stakeholders to propose to the Environmental Management Commission an Advanced Clean Trucks (ACT) program that would ensure zero-emission trucks and buses are available for purchase in the State. The overall goal of ACT is to develop a self-sustaining zero-emission truck market by requiring vehicle manufacturers to sell zero-emission vehicles as an increasing percentage of their annual MHD sales through 2035. Under the program, manufacturers would be responsible for offering ZEV sales shares of 10-13% in 2026, increasing to 40-75% in 2035, depending on vehicle size.
- The scale of deployment for all vehicle classes will require continued buildout of a robust network of electric vehicle charging infrastructure for personal vehicles and fleets and coordination with neighboring states. Managing the timing and location of electric vehicle charging infrastructure deployment will continue to be critical to reduce costs and enhance system reliability.

## Building Decarbonization

Achieving widespread building decarbonization will require updated codes and standards, deployment of more efficient and electric appliances, and integrated electric system planning. **Space heating and water heating applications will be the most important to replace,** as they are responsible for around half of direct building emissions today. However, they are also among the most expensive appliances to purchase.

- Building codes and appliance standards can lay the foundation for achieving zero-emission homes, apartments, and businesses. New buildings have been shown to be the most cost-effective electrification opportunities in multiple regions across the country[53], so all-electric or carbon-neutral building standards should be considered in the 2030 timeframe.
- Most buildings that will be standing in 2050 in North Carolina have already been built, so understanding opportunities for building retrofits will be critical. Some buildings will be easier and cheaper to retrofit with all-electric appliances, including buildings that have been built more

[53] https://rmi.org/wp-content/uploads/2018/06/RMI_Economics_of_Electrifying_Buildings_2018.pdf

recently and those with existing central AC systems.[54] Additionally, prioritizing energy efficiency (in particular, weatherization programs and building insulation) can help lessen the costs of building decarbonization.

+ In addition to all-electric buildings, other solutions such as hybrid systems or networked geothermal systems may be better for older buildings or those connected to older gas distribution systems. Hybrid heating solutions, where a customer would keep their existing natural gas furnace and install an electric heat pump for air conditioning and for displacing a portion of heating needs, have been shown to reduce the costs of decarbonization significantly.[55] North Carolina would benefit from more planning to evaluate the challenges associated with a shift to electrified space heating in the winter and the tradeoffs with reliable electric grid planning.

+ Educating home and building owners is key to decarbonizing buildings as owners need to better understand technologies, costs, and incentive programs. Robust training and education programs for the energy workforce regarding hybrid and full electrification in building retrofits will be important to achieve the scale of deployment of more efficient space heating systems.

## Short-Lived Climate Pollutants

Short-lived climate pollutants (SLCPs) include methane and HFCs, which have an outsized impact on the climate over a shorter time horizon. For this reason, **actions to reduce SLCP emissions should be prioritized.** In the Net-Zero Scenarios, methane emissions in 2030 are almost 30% lower than those of the Reference Scenario due to actions reducing emissions from agriculture, waste, and fugitive leaks from the gas transmission and distribution system. For HFCs, significant reductions are expected to occur due to the recently finalized EPA HFC Allowance Allocation and Trading Program established under the AIM Act, federal legislation that directed the EPA to phase down production and consumption of HFCs by 85% below baseline levels (the average annual emissions from 2011-2013) by 2036[56].

## Research Emerging Technologies

Some of the technologies needed to achieve net zero in North Carolina are still being researched and developed to determine the best applications and to bring down costs. This includes the **commercialization of decarbonized fuels (e.g., green hydrogen or advanced hydrogen), long-term energy storage systems, negative emissions technologies (e.g., DAC), and innovation in agriculture, waste, and industrial processes**.

+ Many federal and regional efforts are already underway to scale up a role for low-carbon hydrogen created through renewable electrolysis (e.g., green hydrogen). In November 2022, a coalition of major electric utilities, technology companies, and other hydrogen users from a variety of industries across six states announced plans to develop a Southeast Hydrogen Hub. The coalition

[54] https://www.ethree.com/e3-releases-integrated-decarbonization-study-for-baltimore-gas-and-electric/

[55] Historically, hybrid systems have been operated via contractor or user-defined temperature setpoints at which a backup thermal system takes over from the heat pump. However, utilities in both Canada and the United Kingdom have begun to pilot alternative control strategies that leverage differences in gas versus electric pricing, weather conditions, and other factors to optimize the operation of hybrid systems to ensure there are system benefits.

[56] https://www.epa.gov/climate-hfcs-reduction/final-rule-phasedown-hydrofluorocarbons-establishing-allowance-allocation

will compete for funding under the U.S. Department of Energy's $8 billion program for regional hydrogen hubs as part of BIL to develop and scale projects across the Southeast. This effort presents a potential opportunity to better understand hydrogen delivery and storage opportunities in the region and enhance coordination with neighboring states and the Department of Energy.

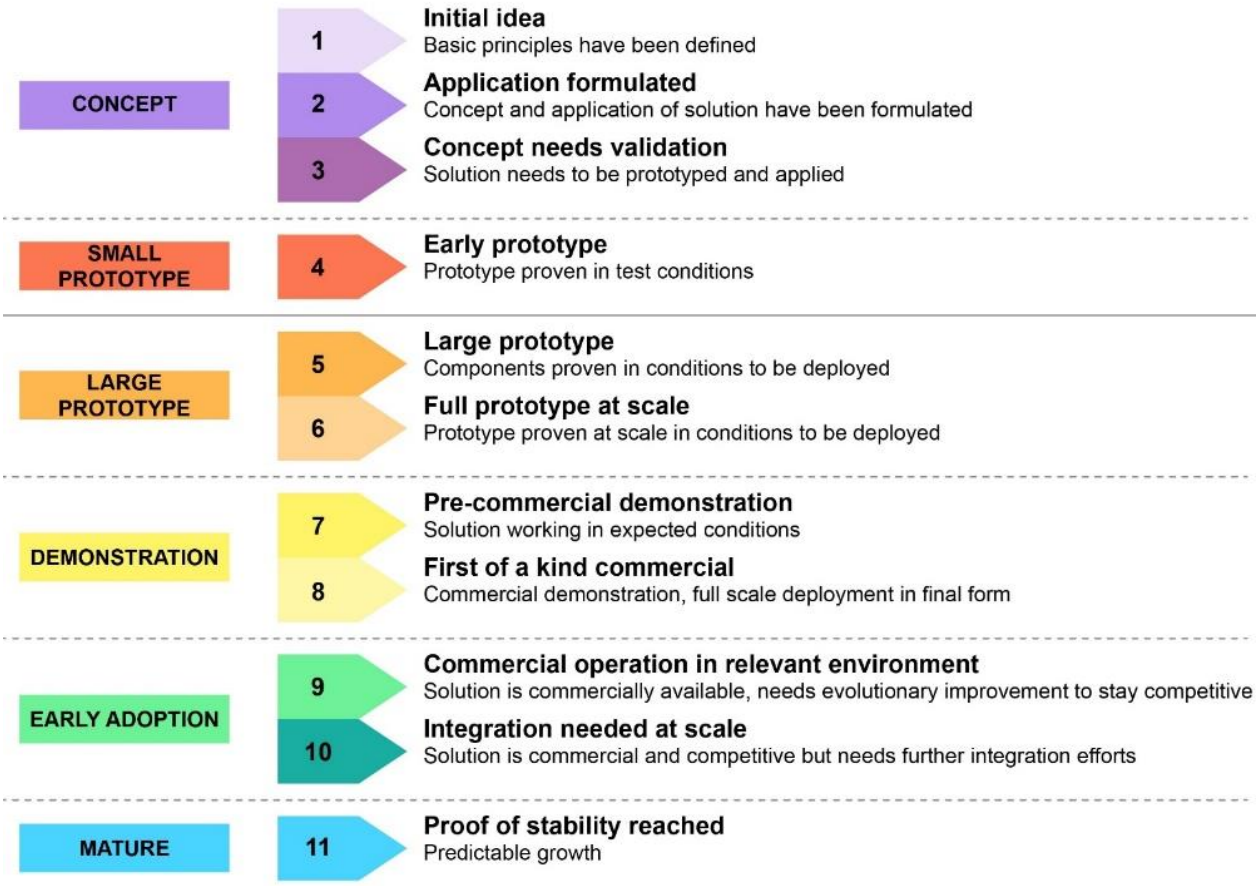
- North Carolina will continue to collaborate with and learn from other states on economy-wide decarbonization efforts. In December 2022, the U.S. Climate Alliance (of which North Carolina is a member state) released a new guidebook that outlines strategies for state policymakers to reduce GHGs from the industrial manufacturing sector. This resource draws from a landscape analysis of more than 100 state policies to detail multiple policy levers that states can utilize to reduce emissions.
- This Pathways Analysis envisions the potential for an advanced biofuels market in one of the Net-Zero Scenarios that would utilize waste and residue feedstocks to produce renewable natural gas and renewable diesel for hard-to-decarbonize applications, such as industry and trucking. North Carolina should explore piloting advanced biofuel opportunities to advance renewable diesel potential for hard-to-electrify applications.
- The agriculture, waste, and industrial process sectors are likely to be among the more challenging and expensive to achieve deep decarbonization, so additional effort will be needed to explore innovative approaches to further reduce emissions. In the net-zero scenarios, the agriculture sector can achieve a 40% reduction in emissions by 2030 (relative to 2018 levels), which is critical to achieving the State's economy-wide GHG target in 2030.

## Long-Term (2035-2050) – Deploy the Next Phase of Solutions

After 2035, North Carolina will need to move to deploy the next phase of solutions, tackling some of the more challenging applications such as industry, agriculture, waste, and off-road transport applications.

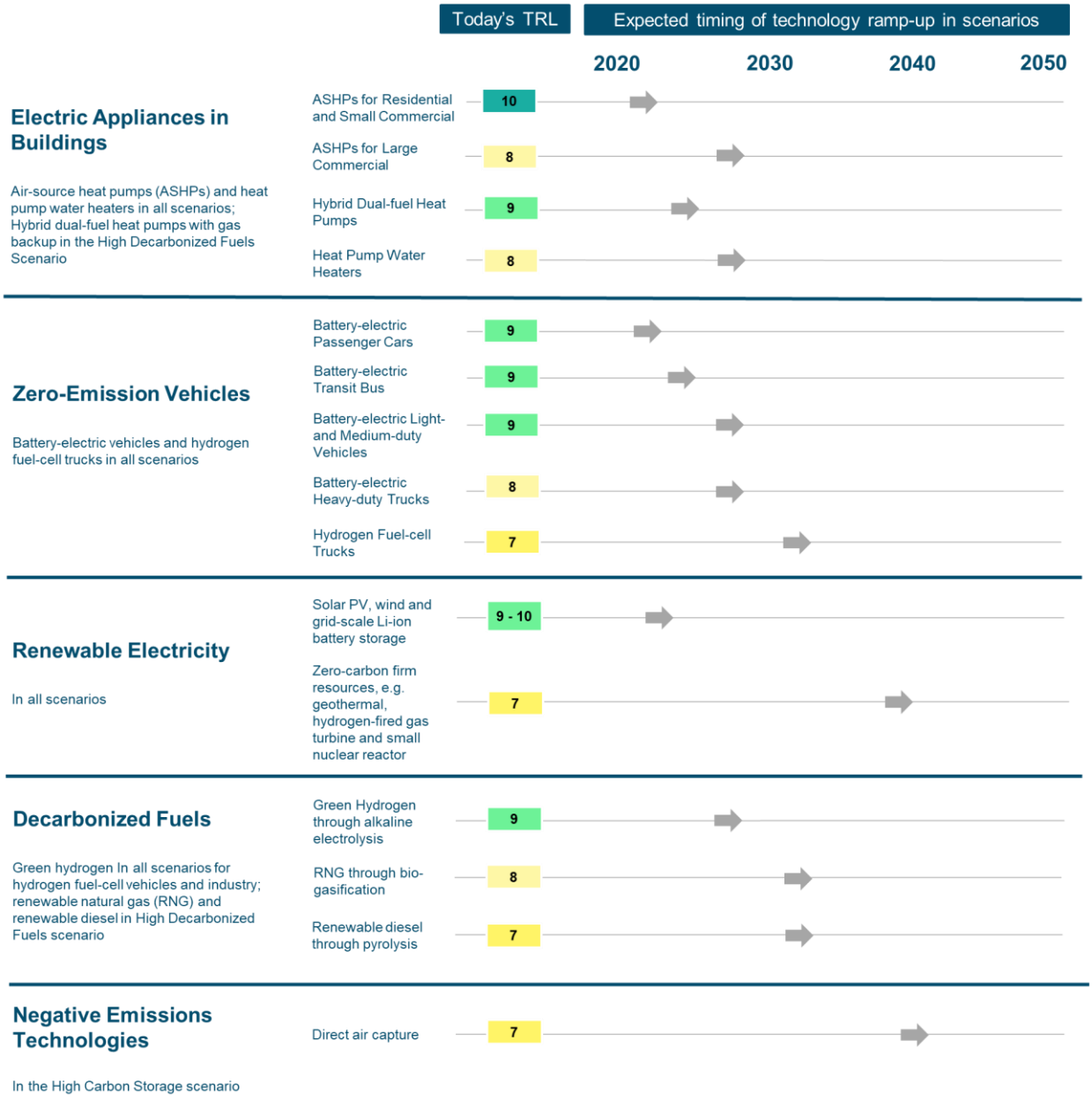
- Many technologies that could support a cost-effective transition to deep decarbonization are still in the early stages of commercialization and deployment. The International Energy Agency (IEA) has developed a set of Technology Readiness Levels (TRLs) that measure the current state of commercialization of decarbonization measures. This scale ranges from Level 1 (initial conceptual idea) to Level 11 (mature technology with proof of stable and predictable growth). All decarbonization pathways scenarios include technologies that are at least a Level 5 (prototyped and at pre-commercial demonstration) to ensure that we do not rely on technologies that are too nascent. Additional research, development, and deployment will be needed to commercialize a full portfolio of options. In particular, additional support will be needed to commercialize advanced biofuels, green hydrogen, ZEVs for all vehicle classes, industrial electrification, and DAC.

***Figure 41.*** *Technology Readiness Level Scale from International Energy Agency*[57]




[57] TRL scale applied by the IEA: https://www.iea.org/reports/clean-energy-innovation/innovation-needs-in-the-sustainable-development-scenario

***Table 9.*** *Technology Readiness Level of Key Technologies*




+ Research and development will need to continue in the 2020s and 2030s to ensure that solutions can be deployed at scale to reach 2050 goals. In particular, this analysis identified key technologies that are in demonstration phases today and will be critical for reaching net zero by midcentury. A coordinated research and development effort will need to accelerate the commercialization of these key technologies in the next decade, **including hydrogen fuel-cell trucks, production of hydrogen, renewable natural gas and renewable diesel, zero-carbon firm electricity-generating resources, long-term energy storage, and negative emissions technologies** (e.g., DAC). It is important for the State to initiate and pursue new processes supporting long-term research and

development in coordination with regional partners, federal programs, national labs, and academic institutions.

+ North Carolina should continue to ramp up efforts to increase carbon storage and sequestration from natural and working lands over the long term. These efforts should be built on research and development efforts from the previous decade or so and focus on transformative actions, including protecting and restoring forests and wetlands in flood-prone areas, facilitating landowner participation in carbon offset and ecosystem services markets, and integrating climate adaptation and resiliency strategies into local government planning.

# Conclusion

EO 246 called for the development of this Pathways Analysis to help North Carolina achieve its climate goals and realize the full benefits of the clean energy economy. The PATHWAYS modeling, bolstered by diverse stakeholder feedback and technical expertise, furthers our understanding of the tradeoffs between different emission-reduction strategies and identifies powerful near-term actions to reduce emissions.

The three Net-Zero Scenarios in this report demonstrate there is no single path to reaching the State's long-term goals – every decarbonization strategy presents unique considerations and impacts. **Despite long-term uncertainty, there is still a critical need for immediate, ambitious, and sustained action. Thankfully, there are powerful "no-regret" strategies that are consistent across the Net-Zero Scenarios and can be pursued in the near-term**. The section **Roadmap to Net-Zero** outlines some of the most compelling opportunities to reduce emissions, including implementing the Carbon Plan under HB 951 and accelerating the decarbonization of the electricity grid, expanding the benefits of cleaner electricity with electric vehicles and electric appliances, or maximizing cost-effective energy efficiency through the improvement of building shells and reducing vehicle miles traveled. As North Carolina scales proven technologies in the near- and mid-term, ongoing research and commercialization of emerging technologies will also be critical to getting the next phase of solutions ready for industrial applications and other harder-to-decarbonize sectors.

Achieving North Carolina's net-zero vision requires continued partnership across the public and private sectors, evolving research and analysis, and the inclusive engagement of constituencies across the State. While this Pathways Analysis establishes an important foundation for climate planning, continual and transparent monitoring, reporting, and tracking of progress is necessary to ensure North Carolina remains on a path to achieve its GHG goals. More work is also needed to reduce emissions in an affordable, equitable, and reliable manner. Further research and engagement on topics like environmental justice and economic impacts will complement this analysis and benefit North Carolina businesses and communities across the State. Moving forward, the Cooper Administration will work to implement the identified strategies and evaluate opportunities to continually update and refine this Pathways Analysis to keep the State aligned with the latest research, technology commercialization, and deployment progress and ultimately achieve a net-zero future for North Carolina.

# Appendix A Supplemental Information on Stakeholder Engagement

Consulting firm Energy and Environmental Economics (E3) and the North Carolina Governor's Policy Office ensured timely consultation with and feedback from various entities and stakeholders in North Carolina throughout the Pathways Analysis as below.

***Key Entities and Stakeholders Involved Regularly Throughout the Pathways Analysis***

| Entity | Key Responsibilities | Project Involvement |
|---|---|---|
| Interagency Steering Committee | Provide data, subject matter expertise, and input on key decision points (e.g., scenarios and framing)<br>Ensure the analysis is aligned with and supportive of parallel efforts in the State and ongoing work in other agencies | Monthly consultation meetings with E3 and the Governor's Policy Office; with a total of 10+ meetings including follow-ups with individual agencies |
| Technical Advisory Group | Provide technical feedback at key decision points<br>Keep the analysis informed by subject matter expertise | 4 meetings throughout the study |
| Other Targeted Stakeholders | Share status updates on progress and solicit timely feedback | 5 meetings with natural and working lands experts, buildings experts, environmental groups, environmental justice communities, etc. |
| General Public | Share status updates on progress and solicit general feedback | 3 meetings throughout the study |

**Interagency Steering Committee Membership**

- Office of Governor Roy Cooper
- North Carolina Department of Commerce
- North Carolina Department of Environmental Quality
- North Carolina Department of Natural and Cultural Resources
- North Carolina Department of Transportation

**List of Technical Advisory Group Members**

- Academic Research
  - Robert Cox - Associate Director, UNC Charlotte Energy Production and Infrastructure Center
  - Jeremiah Johnson - Associate Professor, North Carolina State University Department of Civil, Construction and Environmental Engineering

- Brian Murray - Interim Director, Duke Nicholas Institute for Energy, Environment and Sustainability

- Land Use, Land-Use Change, and Forestry
  - Justin Baker - Associate Professor, NC State University
  - Lydia Olander - Director of the Ecosystem Services Program, Duke University
- Power Sector
  - Ward Lenz - Executive Director, North Carolina Sustainable Energy Association
  - Mark McIntire - Director of Government Affairs, Energy and the Environment and Stakeholder Engagement, Duke Energy Corporation
  - Michael Youth - Government and Regulatory Affairs Counsel, North Carolina's Electric Cooperatives
- Public Interest
  - Amanda Levin - Interim Director of Policy Analysis, Natural Resources Defense Council
  - Al Ripley - Director, Consumer, Housing and Energy Project, North Carolina Justice Center (succeeded by Claire Williamson, Energy Policy Advocate, North Carolina Justice Center)
  - Sherri White-Williamson - Environmental Justice Policy Director, North Carolina Conservation Network
- Residential, Commercial, and Industrial
  - Kevin Martin - Executive Director, Carolina Utility Customers Association
  - Thomas Phoenix - Principal, CPL Architects and Engineers
  - Ross Smith - President, North Carolina Manufacturers Alliance
- Transportation Sector
  - Heather Brutz - Transportation Finance and Operations Manager, North Carolina Clean Energy Technology Center
  - Catherine Kummer - Sustainability, Resiliency, and Governmental Affairs Officer, Charlotte Area Transit System

# Appendix B Detailed PATHWAYS Modeling Approach and Assumptions

## PATHWAYS Modeling Approach

E3 used the PATHWAYS model to analyze decarbonization pathways for North Carolina. The PATHWAYS model is an economy-wide representation of infrastructure, energy use, and emissions within a specified geography. The model allows comparison of user-defined scenarios of future energy demand and emissions to answer "what if" questions related to decarbonization. PATHWAYS can be used as a tool to explore the impacts and implications of potential climate and energy policies specified by the user, but it is not designed to produce scenarios that represent the "optimal" or "likeliest" pathways to meeting emissions targets, as future technology availability and costs are highly uncertain.

E3 created the PATHWAYS model to help policymakers, businesses, and other stakeholders analyze trajectories to achieving deep decarbonization of the economy, and the model has been improved over time in projects analyzing decarbonization at the utility service territory, state, and national level. Recent examples include work with the California Energy Commission, the New York State Energy Research and Development Authority, and the Colorado Energy Office.

E3 built bottom-up PATHWAYS models for North Carolina using the Long-Range Energy Alternatives Planning system (LEAP), a scenario-based modeling tool that tracks energy consumption and greenhouse gas (GHG) emissions in all sectors of the economy. The model was benchmarked to historical energy consumption and GHG emissions data from the North Carolina 2022 GHG Inventory (2022 Inventory).

A key feature of PATHWAYS modeling is the characterization of stock rollover in major equipment categories (specifically in buildings and transportation fleets). The stock rollover approach tracks the retirement of vehicles and end-use equipment in buildings and their replacement with newer equipment that may have improved performance or may be powered by different fuels. This captures the time lag between changes in annual sales of new equipment and changes in the overall stock of equipment in the economy over time. This is important, as different technologies will have different lifetimes. Some technologies, such as lightbulbs, might have lifetimes of just a few years, while others, such as building shells, can have lifetimes of decades. By accounting for this dynamic, a PATHWAYS scenario can determine the pace of technology deployment necessary to achieve economywide GHG goals or policy targets. In addition to subsectors that track the stock rollover of equipment, there are subsectors in the PATHWAYS model that track energy demand only (in the case of industrial subsectors where equipment is highly diverse, and few data are available) or GHG emissions only (in the case of subsectors where emissions are unrelated to fuel combustion). The table below shows the full list of subsectors included in the PATHWAYS model.

*PATHWAYS Model Subsectors by Type*

| Subsector Type | Subsector Name | Subsector Type | Subsector Name |
|---|---|---|---|
| Stock Rollover | Residential Building Shell | Energy Only | Residential Other |
| Stock Rollover | Residential Central Air Conditioning | Energy Only | Commercial Other |
| Stock Rollover | Residential Room Air Conditioning | Energy Only | Transportation Aviation |
| Stock Rollover | Residential Clothes Drying | Energy Only | Transportation Other |
| Stock Rollover | Residential Clothes Washing | Energy Only | Industry Agriculture |
| Stock Rollover | Residential Cooking | Energy Only | Industry Construction |
| Stock Rollover | Residential Dishwashing | Energy Only | Industry Mining and Upstream Oil and Gas |
| Stock Rollover | Residential Freezing | Energy Only | Industry Aluminum |
| Stock Rollover | Residential General Service Lighting | Energy Only | Industry Cement and Lime |
| Stock Rollover | Residential Exterior Lighting | Energy Only | Industry Chemicals |
| Stock Rollover | Residential Linear Fluorescent Lighting | Energy Only | Industry Food |
| Stock Rollover | Residential Reflector Lighting | Energy Only | Industry Glass |
| Stock Rollover | Residential Refrigeration | Energy Only | Industry Iron and Steel |
| Stock Rollover | Residential Single Family Space Heating | Energy Only | Industry Metal Based Durables |
| Stock Rollover | Residential Multi Family Space Heating | Energy Only | Industry Paper |
| Stock Rollover | Residential Water Heating | Energy Only | Industry Plastics |
| Stock Rollover | Commercial Air Conditioning | Energy Only | Industry Refining |
| Stock Rollover | Commercial Cooking | Energy Only | Industry Wood Products |
| Stock Rollover | Commercial High Intensity Discharge Lighting | Energy Only | Industry Other |
| Stock Rollover | Commercial Linear Fluorescent Lighting | Emissions Only | Agriculture |
| Stock Rollover | Commercial General Service Lighting | Emissions Only | Coal Mining |
| Stock Rollover | Commercial Refrigeration | Emissions Only | Natural Gas and Oil Systems |
| Stock Rollover | Commercial Ventilation | Emissions Only | Industrial Processes |
| Stock Rollover | Commercial Space Heating | Emissions Only | Waste |
| Stock Rollover | Commercial Water Heating | Emissions Only | LULUCF |
| Stock Rollover | Transportation Light Duty Cars | | |
| Stock Rollover | Transportation Light Duty Trucks | | |
| Stock Rollover | Transportation Light Medium Duty Trucks | | |
| Stock Rollover | Transportation Medium Duty Trucks | | |
| Stock Rollover | Transportation Heavy Duty Trucks | | |
| Stock Rollover | Transportation Buses | | |

## Modeling of Building Shell Improvement

Updated building codes for new residential construction and widespread retrofits of existing building shells are integral measures to all three Net-Zero Scenarios. E3 used Pacific Northwest National Laboratory's *Cost-Effectiveness of the 2021 International Energy Conservation Code (IECC) for Residential Buildings in North Carolina* to estimate the reduction in space heating and cooling demands for new homes when moving to the 2021 IECC compared to the 2015 IECC with amendments (the current standard in North Carolina)[58]. Based on the Statewide average reduction in heating and cooling energy costs, the reduction in annual space heating and cooling demands was estimated to be 8% and 19%, respectively. In the Net-Zero Scenarios, all new housing units constructed after 2025 are assumed to be built to the 2021 IECC.

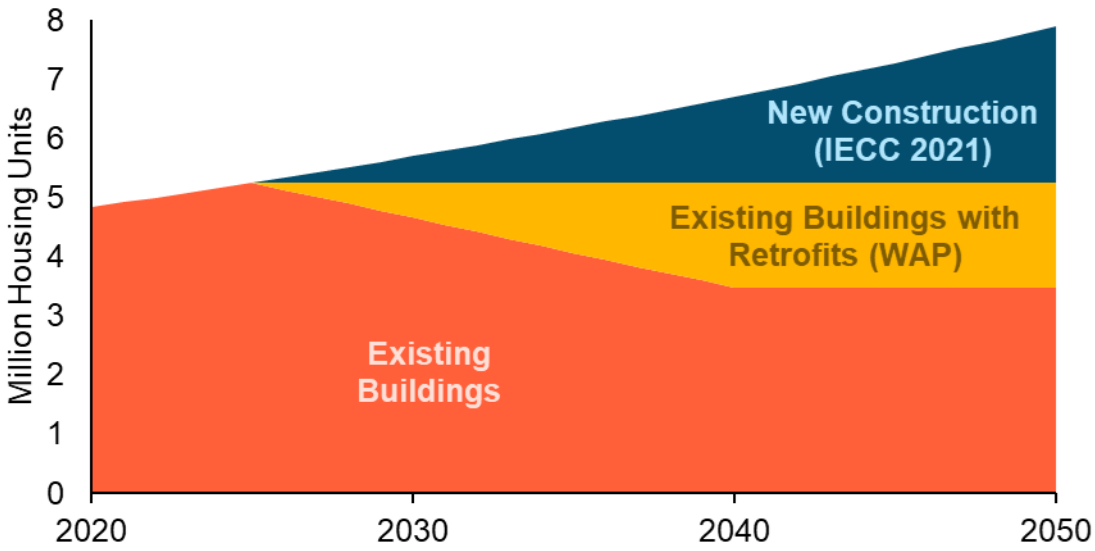
E3 used the *How Energy Efficiency Can Help Rebuild North Carolina's Economy* report from American Council for an Energy-Efficient Economy (ACEEE) to estimate the reduction in space heating and cooling demands and the total penetration of building shell retrofits[59]. The building shell retrofits modeled in PATHWAYS are based on the expansion of the State's existing Weatherization Assistance Program (WAP) as estimated in the ACEEE report, where all eligible households are reached through the program by 2040 (to be eligible, household income must be at or below 200% of the federal poverty level). Using 2020 census data, E3 estimated that 26% of households in North Carolina would be eligible for home energy upgrades through the WAP[60]. Finally, by combining the whole home energy savings from the WAP reported by ACEEE and the average energy demand by end-use outputs from PATHWAYS, E3 estimated that building shell retrofits through the expanded WAP would lead to reductions in space heating and cooling energy demands of 27% and 20%, respectively. The figure below shows the resulting housing stocks by building shell type for the Net-Zero Scenarios.

[58] https://www.energycodes.gov/sites/default/files/2021-07/NorthCarolinaResidentialCostEffectiveness_2021_0.pdf

[59] https://www.aceee.org/research-report/u2007

[60] https://data.census.gov/table?q=North+Carolina+poverty&tid=ACSST5Y2020.S1702

*Annual Residential Housing Units by Building Shell Type in the Net-Zero Scenarios*




## Modeling of Vehicle Miles Traveled

In the PATHWAYS model, total vehicles miles travelled (VMT) is determined by two factors: the average VMT per vehicle and the number of vehicles on the road. Both of these values were benchmarked for the 2018 MOVES[61] modeling performed by the North Carolina Division of Air Quality (DAQ) for the 2022 NC GHG Inventory for the following PATHWAYS vehicle classes[62]:

- Light-Duty Cars
- Light-Duty Trucks
- Light-to-Medium-Duty Trucks
- Medium-Duty Trucks
- Heavy-Duty Trucks
- Buses

In the Reference Scenario, the change in VMT over time is determined by changes to the average VMT per vehicle and population growth (population determines the number of vehicles on the road, as the ratio of vehicles per capita is assumed to hold constant over time in the PATHWAYS scenarios). To estimate the change in VMT between 2018 and 2030, E3 used 2030 outputs from the same MOVES modeling performed by DAQ to determine average VMT per vehicle in that year. While the change in average VMT per vehicle

[61] MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system used by the US Environmental Protection Agency and others to estimate emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics

[62] https://deq.nc.gov/media/27070/download?attachment

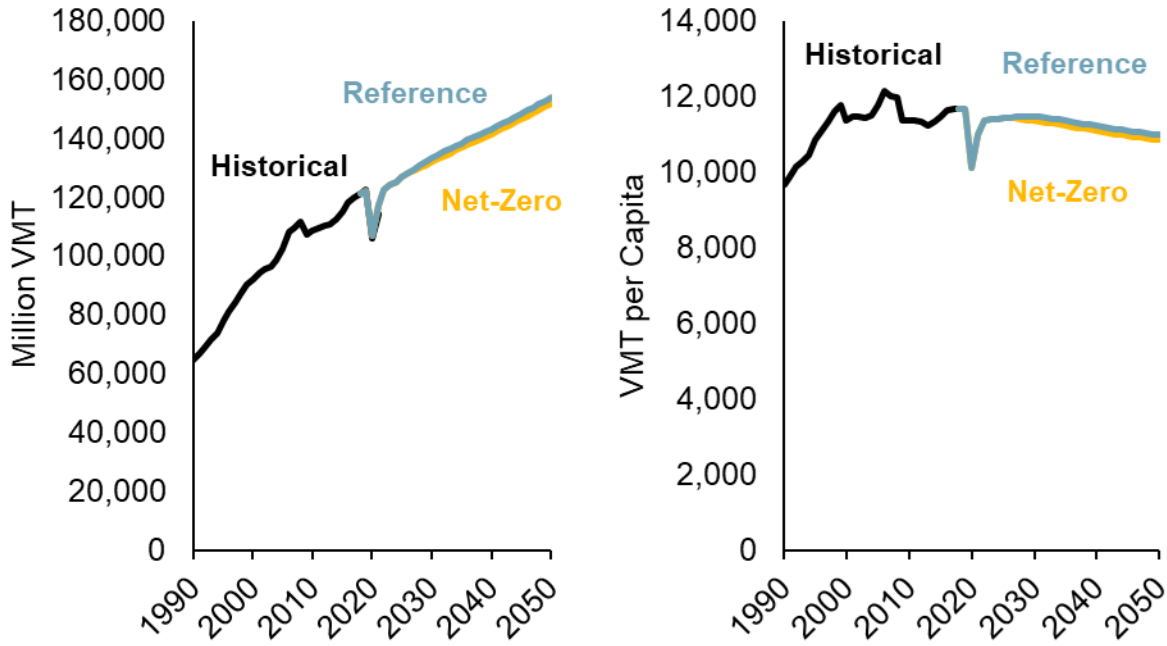
is different for each of the six PATHWAYS vehicle classes, the overall impact is a reduction in the average VMT per vehicle. However, the growth in population between 2018 and 2030 outpaces these per vehicle reductions, and so total VMT grows at an average annual rate of 0.8% over that time period. Because 2030 is the final year of the DAQ MOVES modeling, E3 assumed that these same growth rates would continue through 2050.

In the Net-Zero Scenarios, E3 estimated potential VMT reductions based on measures modeled in the NC Department of Transportation (DOT) *Vehicle Miles Traveled Reduction Study*[63]. The DOT study modeled the impacts of four separate packages, each with a distinct set of VMT reduction measures, for both the Triangle and Asheville regions. The total reduction in daily VMT by 2040 that results from these packages ranged from 0.5% to 0.9% for the Asheville region and from 2.0% to 3.4% for the Triangle region. To estimate statewide VMT reductions from these regional results, E3 assigned either the Asheville or Triangle region results to the 30 urban counties in the State (as defined by the North Carolina Department of Health and Human Services) based on county population[64]. Counties within the Triangle area or with population greater than 300,000 were assigned the Triangle region VMT results, while counties within the Asheville region and the remaining urban counties with populations below 300,000 were assigned the Asheville region results. Fully rural counties were assumed to not have any significant VMT reduction measures in the Net-Zero Scenarios. Using this methodology, the weighted average reduction in total statewide VMT in 2040 was between 0.9% and 1.5% depending on the VMT reduction package selected. Because the exact VMT reduction measures and policies that should be pursued is not the main focus of the economy-wide PATHWAYS analysis, E3 chose to include the average VMT reduction across the four distinct measure packages in the Net-Zero Scenarios, resulting in a 1.2% reduction in total statewide VMT by 2040. The figure below shows the final VMT results by scenario for both the Reference and Net-Zero Scenarios.

[63] https://www.ncdot.gov/initiatives-policies/environmental/climate-change/Documents/vehicle-miles-traveled-reduction-study.pdf

[64] https://files.nc.gov/ncdhhs/RuralUrban_2019.pdf

*Total Annual Statewide VMT and VMT Per Capita for the Reference and Net-Zero Scenarios with Historical Comparison*




## Approach to Decarbonized Fuels

All three Net-Zero Scenarios include the use of decarbonized fuels that are not consumed at any significant level in North Carolina today. Hydrogen is used as a final fuel for industry and freight vehicles in both the High Electrification and High Carbon Storage scenarios, while the High Decarbonized Fuels scenario uses advanced biofuels in addition to hydrogen.

Hydrogen production is not modeled in this analysis, but all hydrogen consumed is assumed to be zero emissions (e.g., produced via electrolysis powered by wind or solar energy). If the hydrogen consumed in these scenarios was produced through a pathway with direct GHG emissions (e.g., steam methane reforming), then those emissions would need to be accounted for and offset by greater emissions reductions elsewhere to achieve the same economy-wide GHG targets.

Production of the advanced biofuels consumed in the High Decarbonized Fuels Scenario was modeled using E3's in-house biofuels production tool. The advanced biofuels produced are treated as chemically identical to fossil fuels, meaning they are not subject to the same blend limits for use in existing equipment as conventional biofuels like ethanol or biodiesel. For this analysis, available feedstocks were determined using the Department of Energy *2016 Billion-Ton Report* and National Renewable Energy Laboratories

(NREL) estimates of biogas potential in the United States[65,66]. The feedstocks included in those studies can be categorized into three groups

1. **Wastes:** These include animal-related wastes (manure), municipal solid waste (MSW) destined for landfill or incineration disposal, and byproducts of wastewater treatment facilities. These feedstocks require no additional agronomic inputs such as land or fertilizer to produce as they are byproducts of existing economic activities.
2. **Forest and Agriculture Residues:** Forest residue feedstocks include logging residues, wood wastes from mills, and harvest from forest thinning, fuel reduction, and regeneration cuts. Agriculture residue feedstocks include crop residues from corn stover, cereal straws (wheat, oats, and barley), and sugarcane. Both forest and agriculture residues require no additional cultivation of land as they are natural byproducts of existing forestry and agriculture practices.
3. **Dedicated Energy Crops:** These include both cellulosic crops like miscanthus, switchgrass, and sorghum and woody crops like willow, poplar, eucalyptus and other purpose-grown trees. Unlike wastes and residues, these feedstocks require additional cultivation of land, which can be achieved using marginal agricultural lands, converting existing agricultural or forestry land to energy crop production or re-purposing land used for other uses.

The High Decarbonized Fuel Scenario only includes feedstocks from wastes and forest and agriculture residues; no dedicated energy crops are included in this analysis. In addition to screening out dedicated energy crops, the geographic scope for available feedstocks was limited to North Carolina. The High Decarbonized Fuel scenario assumes that the full amount of in-state feedstock potential for wastes and residues will be available by 2050, which results in 19 and 55 TBtu of renewable natural gas and renewable diesel being produced, respectively, in that year.

## Modeling of Land Use and Land-Use Change and Forestry

North Carolina's natural landscape provides large carbon sinks that play an integral role in offsetting remaining gross emissions and achieving net-zero GHG emissions, in addition to providing numerous other economic and ecological benefits. Similar to other sectors of the economy, the net GHG emissions (in this case negative emissions) of the land-use, land-use change, and forestry (LULUCF) sector were benchmarked to the *2022 Inventory* values for 2018. Because business-as-usual forecasts for net emissions from the LULUCF sector were not readily available from State or federal data sources for this analysis, E3 developed a business-as-usual estimate based on potential changes to forest carbon stocks and sea-level rise in the State.

Changes to forest carbon stocks under a business-as-usual case were based on projected forest acreage loss from *Sanchez et al., 2019*, where the impacts of population growth and climate change on water demand were estimated for North Carolina and South Carolina[67]. In this study, the authors estimated that around 187,000 acres of forest land would be lost by 2050 in North Carolina. Since the total amount of

[65] https://www.energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf

[66] https://www.nrel.gov/docs/fy14osti/60178.pdf

[67] https://www.sciencedirect.com/science/article/abs/pii/S0048969720325675?via%3Dihub#f0035

forest land in the State was 18.76 million acres in 2018, this equates to a loss of around 1% of all forest lands by 2050[68]. To account for this in the business-as-usual forecast of land sinks, E3 reduced the net sequestration from forest carbon flux by 1% between 2018 and 2050, leading to a loss of -0.4 MMT $CO_2e$ of annual sequestration.

To account for the impacts of sea-level rise, E3 relied on estimates of changes to carbon fluxes in coastal habitats in North Carolina and other Mid-Atlantic states in *Warnell et al., 2022*[69]. This study found that under an intermediate projection of sea-level rise, the coastal zones of North Carolina would shift from being a net sink for carbon to a net source. In the first study period (2010-2027), coastal zones in North Carolina have a net annual carbon flux of around -1 MMT $CO_2e$, but by midcentury (2050-2062), this shifts to just under 1 MMT $CO_2e$, meaning the net impact is in annual increase of around 2 MMT $CO_2e$ above current levels. The total estimated impact of forest land loss and sea-level rise in this analysis is a reduction in net sequestration from the LULUCF sector from -42.3 MMT $CO_2e$ in 2018 to -39.9 MMT $CO_2e$ in 2050. This business-as-usual projection is used in all PATHWAYS scenarios.

While the Reference, High Electrification, and High Decarbonized Fuels Scenarios do not include any mitigation measures for the LULUCF sector, the High Carbon Storage Scenario includes two key measures to increase the size of the LULUCF sink. The first is reforestation, which was estimated using the 2020 *North Carolina Natural and Working Lands Action Plan*[70]. While the appendix of the report provides quantitative estimates of the carbon sequestration potential of multiple measures, many of the measures overlap in terms of their geographic scope, meaning that their carbon sequestration benefits cannot simply be added together. To avoid this issue, E3 chose to model the reforestation measure quantified in the report, as it is the individual measure with the largest sequestration potential. In addition, E3 chose to model the "limited scope" estimates of reforestation potential, as the "full scope" estimates to include many land uses that are not likely to be converted to forests (e.g., active agriculture and pasture lands). The total impact of this measure is an increase in annual net sequestration of 3.4 MMT $CO_2e$ by 2050. In addition to increased carbon sequestration from reforestation, E3 estimated that gross emissions from the LULUCF sector could be reduced by 0.4 MMT $CO_2e$ per year by restoring saline tidal flows to impounded coastal areas based on estimates provided in *Warnell et al., 2022*. The combined impact of these two mitigation measures in 2050 is an increase in net sequestration from the LULUCF sector from -39.9 MMT $CO_2e$ in the business-as-usual projection to -43.7 MMT $CO_2e$ in the High Carbon Storage Scenario.

## Modeling of Direct Air Capture

Of the three Net-Zero Scenarios, High Carbon Storage is the only one that requires the use of negative emissions technologies (NETs) to achieve net-zero GHG emissions economy wide by 2050. While there are myriad NETs at various stages of development, E3 assumed that the technology deployed in the High Carbon Storage Scenario is direct air capture (DAC), a process to chemically capture $CO_2$ directly from ambient air. The captured $CO_2$ is then assumed to be injected into suitable geologic formations where it is

[68] https://www.srs.fs.usda.gov/pubs/ru/ru_fs225.pdf

[69] https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000044

[70] https://deq.nc.gov/media/17743/download

permanently sequestered. As of 2022, the International Energy Agency (IEA) reports there are 18 DAC plants operating worldwide, with significantly larger plants in advanced development in the United States[71].

The DAC plant system modeled in this analysis is based on a solid sorbent system directly powered by renewable electricity as shown in a 2019 report from the National Academies Press on NETs[72]. E3 used the mid-point of the low and high estimates for energy requirements to calculate total electricity demand of 1,280 GWh per MMT $CO_2$ captured. This electricity could be supplied with off-grid renewables and the DAC system could be sited wherever low-cost renewables and available land are located. E3 assumes that there are no GHG emissions associated with this process, as the electricity consumed is generated from renewable resources. While there are other potential DAC system configurations modeled in the National Academies Press report, these systems are powered by fossil-based electricity and/or fossil combustion for their thermal energy requirements, and as such would require additional DAC deployment to offset these residual emissions. Finally, previous assessments of geologic sequestration potential have identified relatively little available geologic $CO_2$ storage capacity in North Carolina[73]. While this could limit in-State sequestration, it does not necessarily limit the capture of $CO_2$ via DAC in the State that could be transported via pipeline to another region for sequestration. Furthermore, it remains unclear whether the capture and sequestration of atmospheric $CO_2$ would need to occur within State borders to count as negative emissions in the State's GHG inventory if the capture and sequestration is implemented to offset emissions occurring within North Carolina.

## Approach to the Inclusion of the Inflation Reduction Act of 2022

The Inflation Reduction Act (IRA) contains a vast array of provisions that incentivize the deployment of clean energy technologies and will impact energy and technology costs across virtually all sectors of the economy in the coming years. Estimating the impacts of all the IRA provisions on near- to mid-term technology choices, energy consumption patterns, and GHG emissions in North Carolina was beyond the scope of this project, given time and budget constraints, and early analyses of the IRA from Rhodium Group and the Princeton REPEAT Project focus on national impacts[74,75]. Nevertheless, E3 considered including the impacts of the following key IRA provisions in the PATHWAYS scenarios:

+ Clean Electricity Incentives: While the IRA incentives for clean electricity are expected to lead to larger emission reductions in the power sector than any other sector at the national level based on analyses from Rhodium Group and Princeton, they are not explicitly modeled in this analysis because the PATHWAYS study does not include detailed modeling of the electricity sector and because North Carolina's aggressive electricity sector policies require deep reductions in electricity sector emissions in all scenarios.

[71] https://www.iea.org/reports/direct-air-capture

[72] https://nap.nationalacademies.org/read/25259/chapter/7

[73] https://nicholasinstitute.duke.edu/sites/default/files/publications/carbon-capture-pipeline-and-storage-a-viable-option-for-north-carolina-paper.pdf

[74] https://rhg.com/research/climate-clean-energy-inflation-reduction-act/

[75] https://repeatproject.org/docs/REPEAT_IRA_Prelminary_Report_2022-08-12.pdf

- **Residential Heat Pump Incentives:** The IRA includes incentives for residential heat pumps both for targeted low- and moderate-income populations (through the High-Efficiency Electric Home Rebate Program) and for the general population (through the extension and increase of the 25C Energy Efficient Home Improvement Tax Credit). Based on internal analysis, E3 estimated an increase in residential heat pump market share of 16% in the Reference Scenario.
- **Passenger Electric Vehicle Incentives:** The revised Clean Vehicle Credit expands the number of passenger electric vehicles that could qualify for a tax credit by removing the manufacturer sales cap (allowing Tesla and GM models to be eligible). However, it is uncertain to what degree manufacturers will be able to shift supply chains over the coming years to meet the sourcing requirements for battery component and critical minerals[76]. Moreover, the new thresholds for vehicle price and customer income also reduces the number of models and customers who are eligible to receive the incentive. Due to the high uncertainty in how many more vehicles will receive the Clean Vehicle Credit and how this will impact adoption over the next 10 years, E3 chose to exclude any impacts to passenger electric vehicle sales in the Reference Scenario from the IRA.
- **Commercial Electric Vehicle Incentives:** The Qualified Commercial Clean Vehicles tax credit covers the incremental cost of an electric vehicle above a diesel vehicle or 30% of the electric vehicle purchase price, whichever is less, up to a maximum of $40k (or $7.5k for small commercial vehicles weighing under 14,000 lbs.). It is important to highlight that the Qualified Commercial Clean Vehicles tax credit does not have the same supply chain requirements as the Clean Vehicle Credit for passenger vehicles. To estimate the impact of the credit on commercial electric vehicle sales, E3 used the forecast of incentive spending through 2031 from the Congressional Budget Office's (CBO) cost estimate of the IRA[77]. This report forecasts that there will be $687 million in Qualified Commercial Clean Vehicles tax credits claimed in 2031. Without any detail provided on which segment of commercial vehicles would be claiming these tax credits, E3 assumed that there would be a 50/50 split in the dollar value of tax credits between the light-to-medium-duty (Class 2b-3 vehicles under 14,000 lbs.) and medium-duty (Class 4-6 vehicles between 14,001-26,000 lbs.) segments. Because the maximum tax credit available for vehicles above 14,000 lbs. is capped $40,000, E3 assumed that this would favor medium-duty vehicles rather than heavy-duty vehicles. E3 then divided the amount of tax credits allocated to each segment ($343.5 million) by the maximum tax credit allowed per vehicle ($7,500 for light-to-medium duty and $40,000 for medium duty) to calculate the number of national vehicle sales that could result from this level of tax credit spending. Finally, the electric vehicle sales for each segment was divided by the total vehicle sales for that segment projected nationally by the EIA *Annual Energy Outlook* to estimate the national sales share for electric vehicles. This sales share was then applied to the Reference Scenario for commercial vehicle sales in North Carolina. The resulting electric vehicle sales shares are 15% and 4% by 2031 for the light-to-medium duty and medium-duty segments, respectively, and the combined electric vehicle sales share for the entire light-to-medium-duty, medium-duty, and

[76] https://etechmonkey.com/index.php/2022/08/18/you-dont-get-a-credit-and-you-dont-get-a-credit-the-impact-of-iras-new-clean-vehicle-credit/

[77] https://www.cbo.gov/system/files/2022-08/hr5376_IR_Act_8-3-22.pdf

heavy-duty (MHDV) sector in 2031 is 4%. While the CBO forecast of incentive spending ends in 2031, E3 assumed that market share would continue to increase for MHDV electric vehicles at a similar rate as 2023-2021, reaching a 20% sales share by 2050.

- **Industry CO2 Capture and Storage (CCS):** The IRA increases the Section 45Q tax credit for $CO_2$ captured from point sources and geologically sequestered from $50/ton to $85/ton. At this level, Rhodium Group has estimated that there could be significant cost-effective CCS opportunities nationally[78]. However, the industries where CCS is cost-effective at this incentive level (e.g., iron and steel manufacturing, refineries, cement production, ethanol refining) are largely absent from North Carolina. As a result, E3 did not include any deployment of industrial CCS in the Reference Scenario as a result of the new IRA incentives.
- **Methane Fee:** The Methane Reduction Program in the IRA places a fee on methane emissions from oil and gas facilities that report more than 25,000 metric tons of $CO_2e$ per year in GHG emissions for any emissions above a specified emissions threshold. Because the methane fee only applies to large upstream oil and gas facilities involved in production of oil and gas or processing, transmission, and storage, E3 determined that there would be minimal direct impact on emissions in North Carolina, which is not a major producer of oil and gas. Therefore, no emission reductions were assumed in the Reference Scenario due to the methane fee.
- **Hydrogen Production Incentives:** The IRA includes a significant production tax credit for hydrogen. Similar to commercial electric vehicles, E3 based assumptions on hydrogen use in the Reference Scenario on the CBO forecast of hydrogen incentive spending in their cost estimate for the IRA. The total incentive spending for hydrogen production in the CBO report is just over $2.1 billion nationally in 2031. To align with the prior assumption that all hydrogen consumed in the PATHWAYS scenarios are emissions-free, E3 assumed that all hydrogen production receiving the $2.1 billion in 2031 qualifies for the maximum credit of $3/kg or $22.2/MMBtu. This results in 95 TBtu of incentivized hydrogen production nationally by 2031. E3 then assumed that North Carolina would consume this hydrogen based on its share of national industrial natural gas demand in 2021 (1.2%), resulting in 1.1 TBtu of hydrogen demand in 2031 in the Reference Scenario. Continued growth in demand was assumed through 2050, resulting in 3.3 Tbtu of hydrogen demand in that year. Because these are relatively small amounts relative to existing industrial natural gas consumption in North Carolina (~113 TBtu), this consumption is assumed to represent small industrial projects and pilot facilities that convert natural gas use to hydrogen.

[78] https://rhg.com/research/carbon-capture-american-jobs-plan/