North Carolina Deep Decarbonization Pathways Analysis

Public Engagement Session #2

October 18th, 2022

Office of Governor Roy Cooper

Energy+Environmental Economics

Agenda

+ **Welcome – Office of Governor Roy Cooper (10 min)**
+ **E3 Background and Project Overview – E3 (10 min)**
+ **Draft Scenario Results – E3 (40 min)**
  - Reference Scenario and IRA
  - Mitigation Scenario Results
  - Preliminary Key Findings
+ **Public Input and Next Steps – E3 and Governor's Office (30 min)**
  - Feedback + Q&A
  - Next Steps

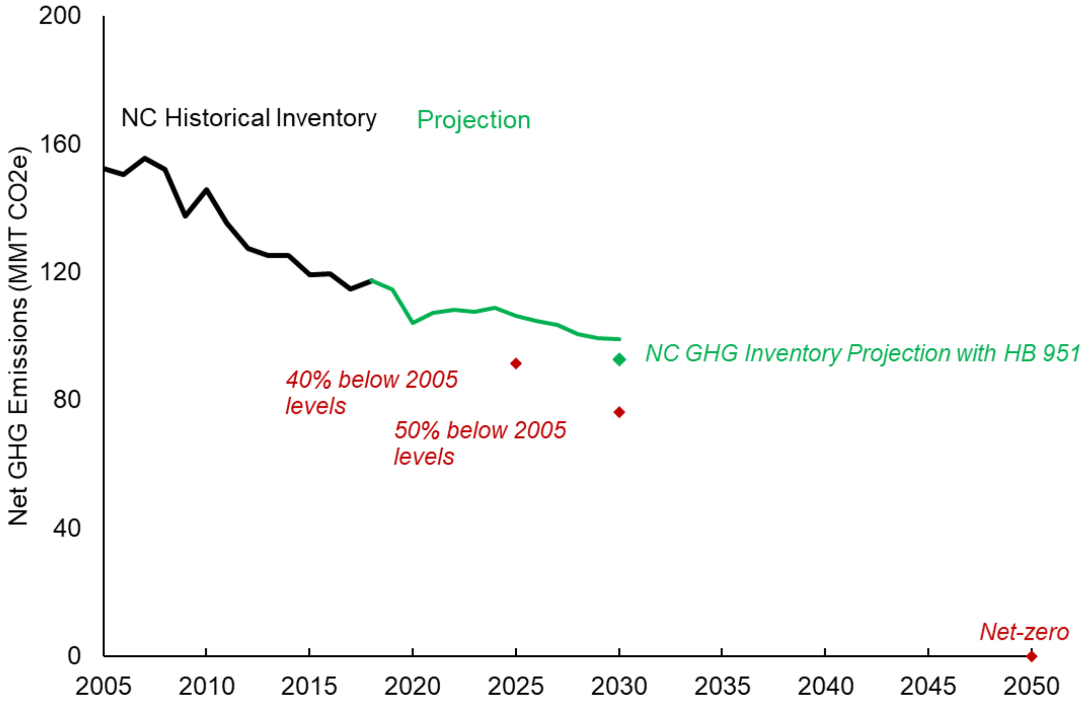
Climate Action in North Carolina

+ **Executive Order No. 246 signed by Governor Cooper in January 2022.**
+ **Establishes new statewide goals to:**
  - Reduce statewide greenhouse gas (GHG) emissions at least 50% below 2005 levels by 2030 and achieve net-zero GHG emissions as soon as possible and no later than 2050; and
  - Increase registered zero-emission vehicles (ZEVs) to at least 1,250,000 by 2030 and increase the sale of ZEVs so that 50% of in-state sales of new vehicles are zero-emission by 2030.
+ **Directs numerous actions to achieve goals in a manner that centers environmental justice and maximizes public health and economic benefits for all North Carolinians.**

NC PATHWAYS Vision + Objectives

- **EO 246 directs the development of a North Carolina Deep Decarbonization Pathways Analysis ("Pathways Analysis") that evaluates potential emission-reduction pathways to achieve these goals**
- **Project Goals**
  - Analyze various technologically feasible GHG emissions reduction pathways to achieve economy-wide 2025, 2030 and 2050 GHG targets.
  - Identify high-level policy and planning takeaways that will inform near-term, mid-term and long-term decarbonization efforts.
  - Equip policymakers and stakeholders with a better understanding of how to effectively reduce emissions across the economy and within specific sectors, building on extensive policy efforts underway and creating synergies with existing initiatives.

North Carolina Net Greenhouse Gas Emissions



Projection based on the 2022 NC GHG Inventory, developed using combination of EPA's Projections Tool module within State Inventory Tool and sector-specific data sources (e.g. MVOES for transportation, Duke forecasts) and incorporate the impact of HB 951

Background on Project

Energy+Environmental Economics

Project Scope

+ Goals

- An analysis of various technologically feasible GHG emissions reduction pathways to achieve NC's economy-wide 2030 and 2050 GHG targets (50 by 2030 and net-zero by 2050)
- Identify high-level policy and planning takeaways

+ Key Tasks and Timeline

#	Task	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	**Project Kickoff and Scenario Scoping**									
2	**Decarbonization Pathways Scenario Analysis**									
3	**Stakeholder Engagement**									
4	**Final Report**									

Stakeholder Engagement

	External Engagement	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	Interagency Steering Committee Meetings									
2	Technical Advisory Group (TAG) Meetings									
3	Targeted Stakeholder Outreach									
4	General Public Engagement Meetings				Aug 11		Oct 18		TBD	

Planned and Proposed Public Engagement Sessions

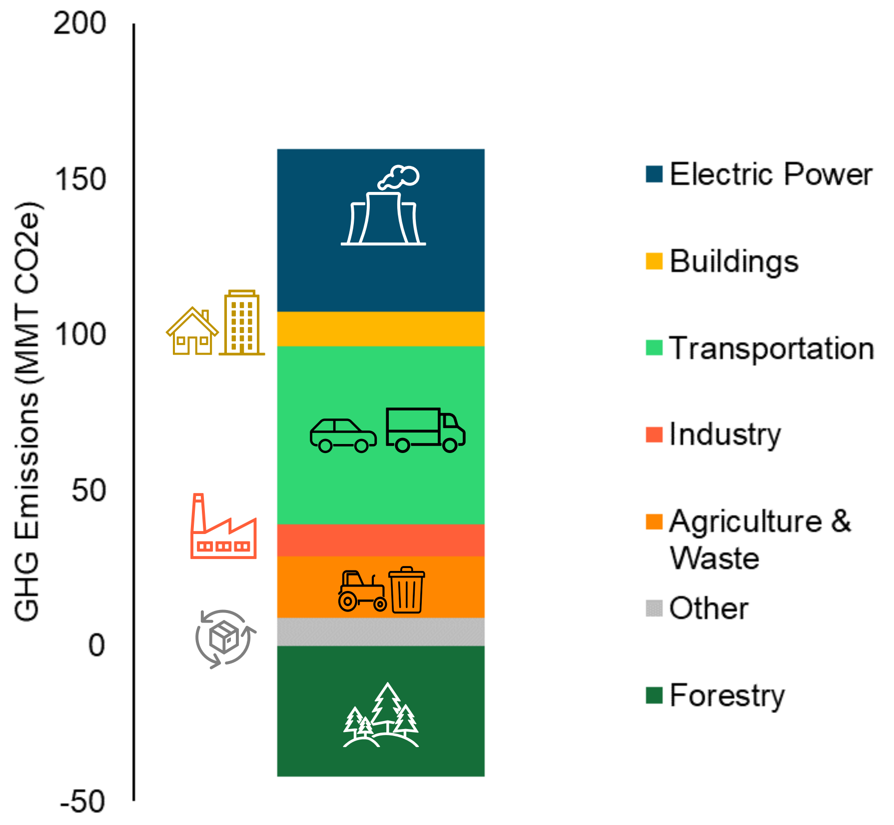
	Aug	Sep	Oct	Nov	Dec	Jan
Planned and Proposed Public Engagement Sessions	●		●		●	

- **Public Engagement Session #1 (August 11):** Introducing the pathways analysis scope, process and scenario design and soliciting public feedback
- **Public Engagement Session #2 (Today):** Presenting draft scenario results and soliciting public feedback
- **Public Engagement Session #3 (TBD in Dec):** Presenting updated final scenario results and soliciting public feedback

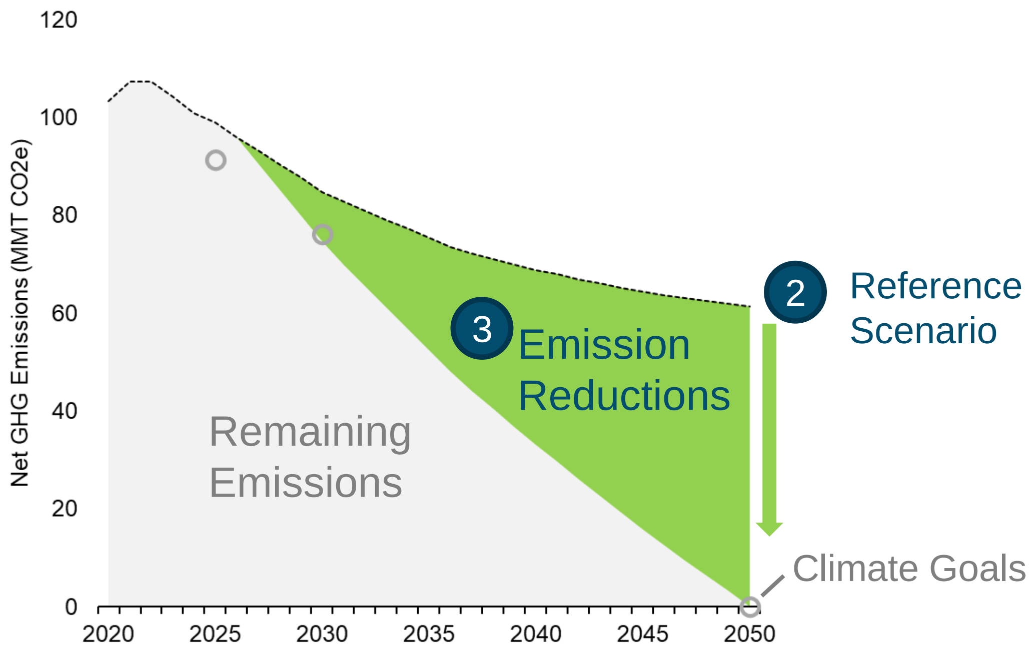
Benchmarking and Draft Reference Scenario Results

Steps of a PATHWAYS study

1 Measure current greenhouse gas emissions in North Carolina



2 Estimate future emissions based on current trends and existing policies

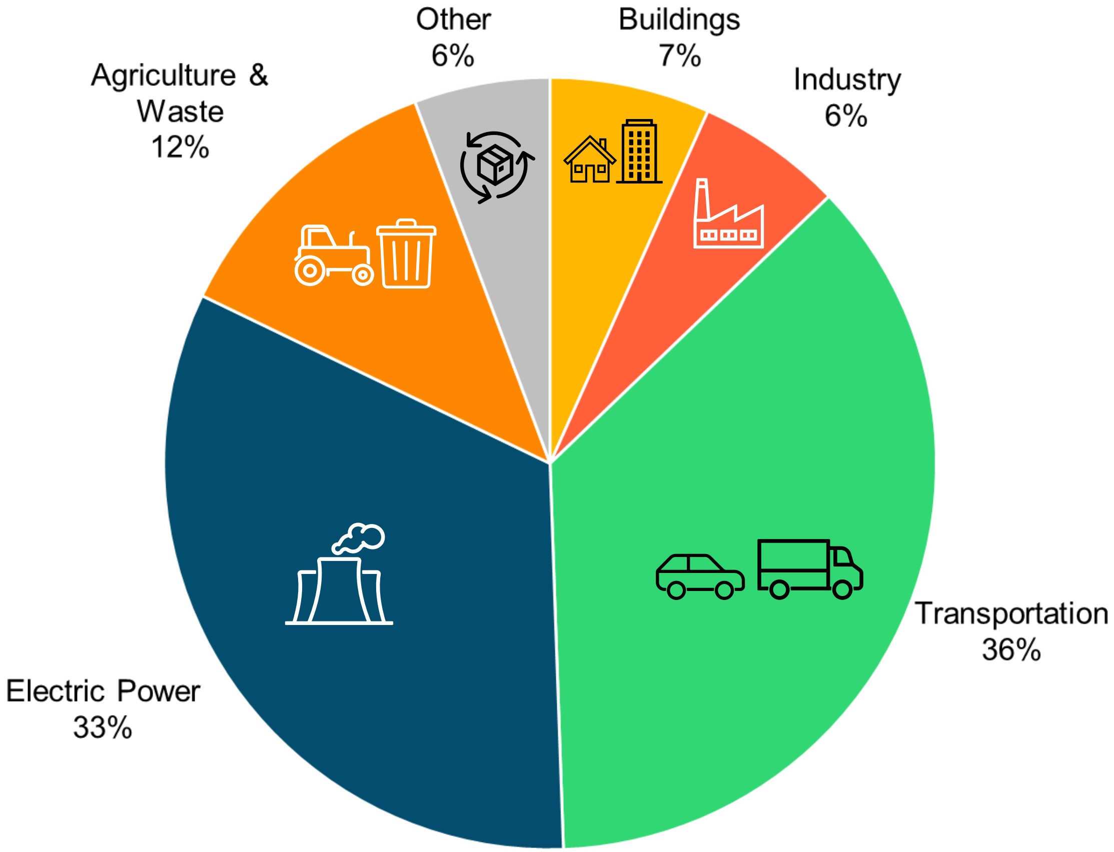


3 Evaluate impact of new potential measures and actions that would help the state meet climate goals

Current emissions profile based on the latest 2022 NC State Greenhouse Gas Inventory

Current Emissions and Initiatives by Sector

1 North Carolina Gross GHG Emissions Profile



Note: Emissions profile 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 Power" category

2 Ongoing Sector-focused Initiatives in NC

- **Clean Transportation Plan**
- **Carbon Plan under the requirement of House Bill 951, NC Clean Energy Plan**
- **Building Code updates**
- **Natural and Working Lands Action Plan**
- **Disbursement of applicable state and federal funding**

Priority actions that impact emissions

Buildings

- Increased sales of high efficiency appliances
- Adoption of improved building shells in both new and retrofit buildings
- All-electric new construction standards
- Increased sales of electrified devices for all end uses (space and water heating, drying, cooking)

Transportation

- Improved fuel economy for new vehicles sold
- Reductions in vehicle-miles traveled through transit and smart growth
- Increased sales of zero-emission vehicles (ZEVs), including, battery-electric and hydrogen fuel cell vehicles

Clean Electricity

- Scale up of renewable electricity sources (wind and solar), and battery storage
- Targeted role for zero-carbon firm generation

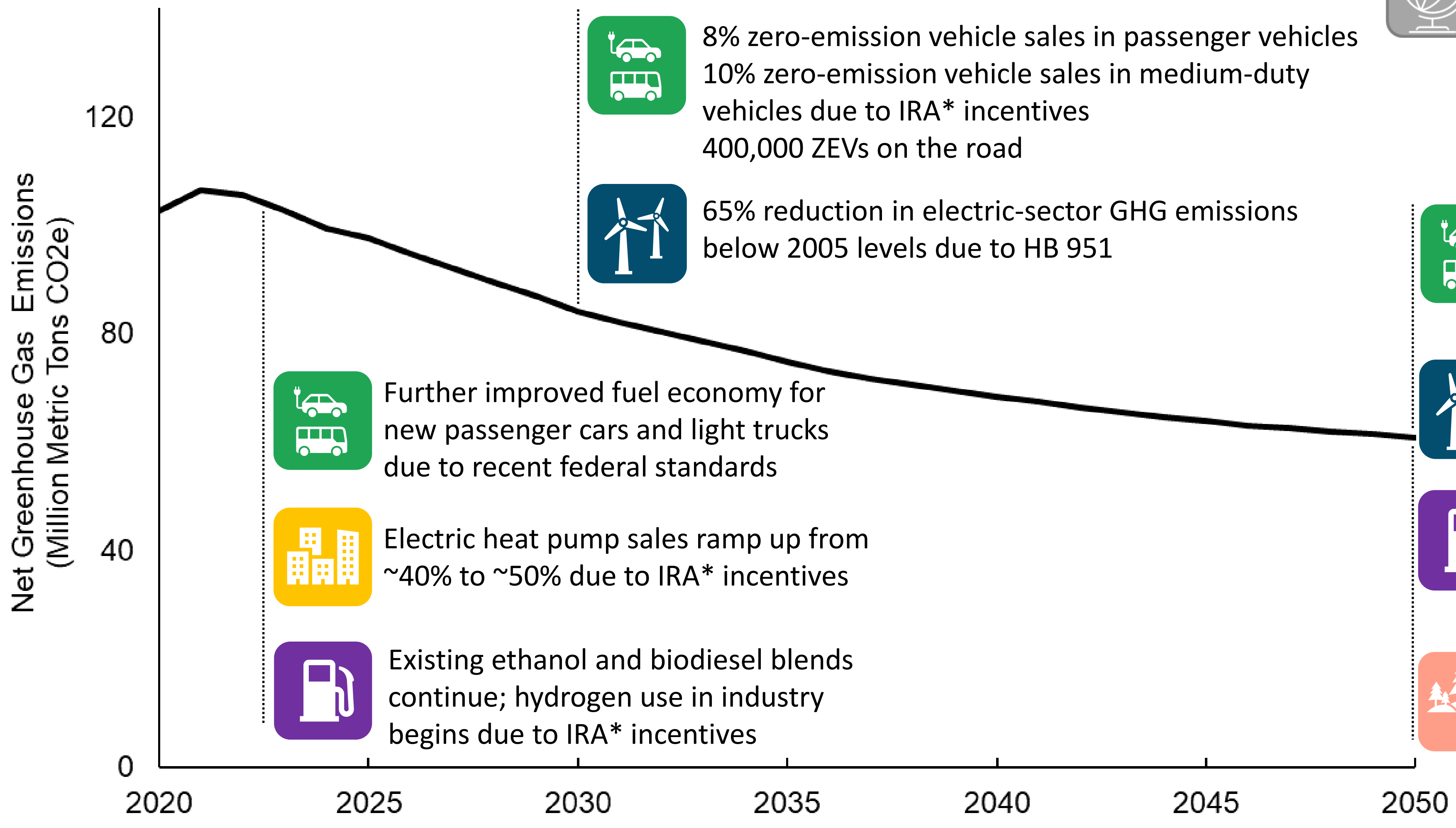
Decarbonized Fuels

- Production of advanced biofuels with sustainable biomass feedstocks
- Production of green hydrogen through electrolysis using renewable electricity

Carbon Sequestration

- Reforestation and restoration to enhance carbon sinks from natural and working lands
- Deployment of negative emissions technologies such as direct air capture of CO2 (DAC)

North Carolina Greenhouse Gas Emissions Reduction Measures Reference Scenario



Population and total vehicle miles travelled (VMT) continue to grow at 0.94%/year, while households and commercial square footage are projected to grow at 1.6%/year and 1%/year respectively.

8% zero-emission vehicle sales in passenger vehicles
10% zero-emission vehicle sales in medium-duty vehicles due to IRA* incentives
400,000 ZEVs on the road

65% reduction in electric-sector GHG emissions below 2005 levels due to HB 951

Further improved fuel economy for new passenger cars and light trucks due to recent federal standards

Electric heat pump sales ramp up from ~40% to ~50% due to IRA* incentives

Existing ethanol and biodiesel blends continue; hydrogen use in industry begins due to IRA* incentives

35% zero-emission vehicle sales in passenger vehicles, 2 million zero-emission passenger vehicles on the road

85% reduction in electric-sector GHG emissions below 2005 levels due to HB 951

13 TBtu of hydrogen use in industry replacing natural gas due to continued trend post IRA* incentives

Existing carbon sequestration through natural and working land declines slightly over time due to projected loss of forests and sea level rise impacts

*Inflation Reduction Act of 2022

Note: Impacts of the Inflation Reduction Act are uncertain, current assumptions in appendix

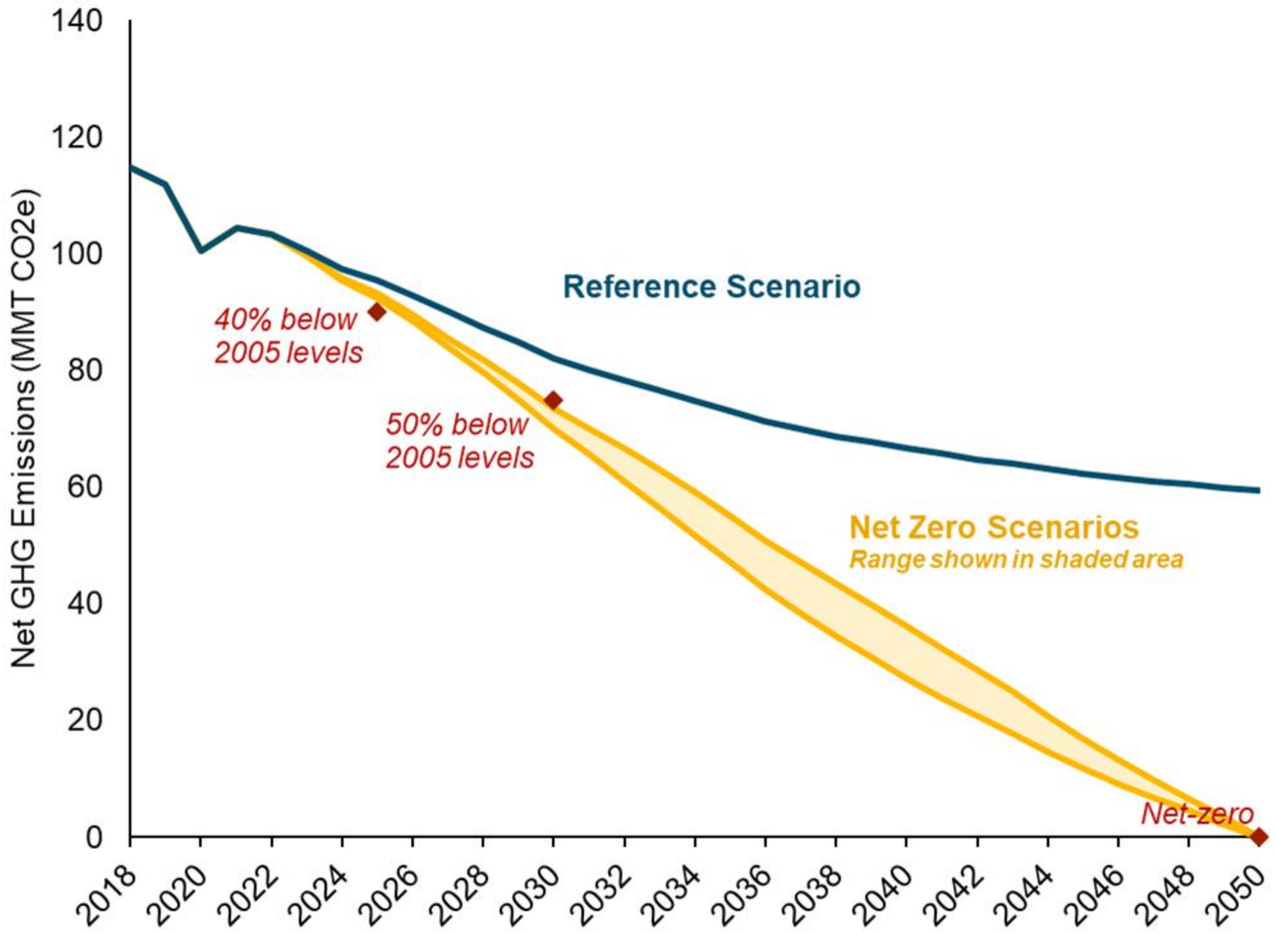
Scenario Design

Net Zero Scenario Design

Level of Transformation by Measure

Measure	Reference Scenario	Scenario 1: High Electrification	Scenario 2: High Decarbonized Fuels	Scenario 3: High Carbon Storage
Efficiency	Low	High	High	High
Building Electrification	Low	Very High	Medium	Medium
Transit and Smart Growth	Low	High	High	Medium
Zero-Emission Vehicles	Low	Very High	High	High
Clean Electricity	High	Very High	Very High	High
Decarbonized Fuels	Low	Low	High	Low
Emissions Mitigation in Ag, Waste & Other	Medium	Medium	Medium	Medium
Carbon Sequestration in Lands and Forests	Medium	Medium	Medium	High
Negative Emissions Technologies	None	None	None	Low

Net GHG Emissions by Scenario



- **All three net zero scenarios have a similar trajectory for net GHG emissions**
  - All net zero scenarios are within 1% of the 2025 GHG target and exceed the 2030 target
  - The exact trajectory will be highly dependent on the electricity sector, which will result from NCUC's decision-making on the Carbon Plan

- **Many of the key differences between the net zero scenarios (e.g., electrification vs. decarbonized fuels vs. carbon storage) have a similar impact on the total net emissions shown here, but have different implications for the nature and timing of the energy system transition in North Carolina**

Priority actions that impact emissions

Buildings

- Increased sales of high efficiency appliances
- Adoption of improved building shells in both new and retrofit buildings
- All-electric new construction standards
- Increased sales of electrified devices for all end uses (space and water heating, drying, cooking)

Transportation

- Improved fuel economy for new vehicles sold
- Reductions in vehicle-miles traveled through transit and smart growth
- Increased sales of zero-emission vehicles (ZEVs), including, battery-electric and hydrogen fuel cell vehicles

Clean Electricity

- Scale up of renewable electricity sources (wind and solar), and battery storage
- Targeted role for zero-carbon firm generation

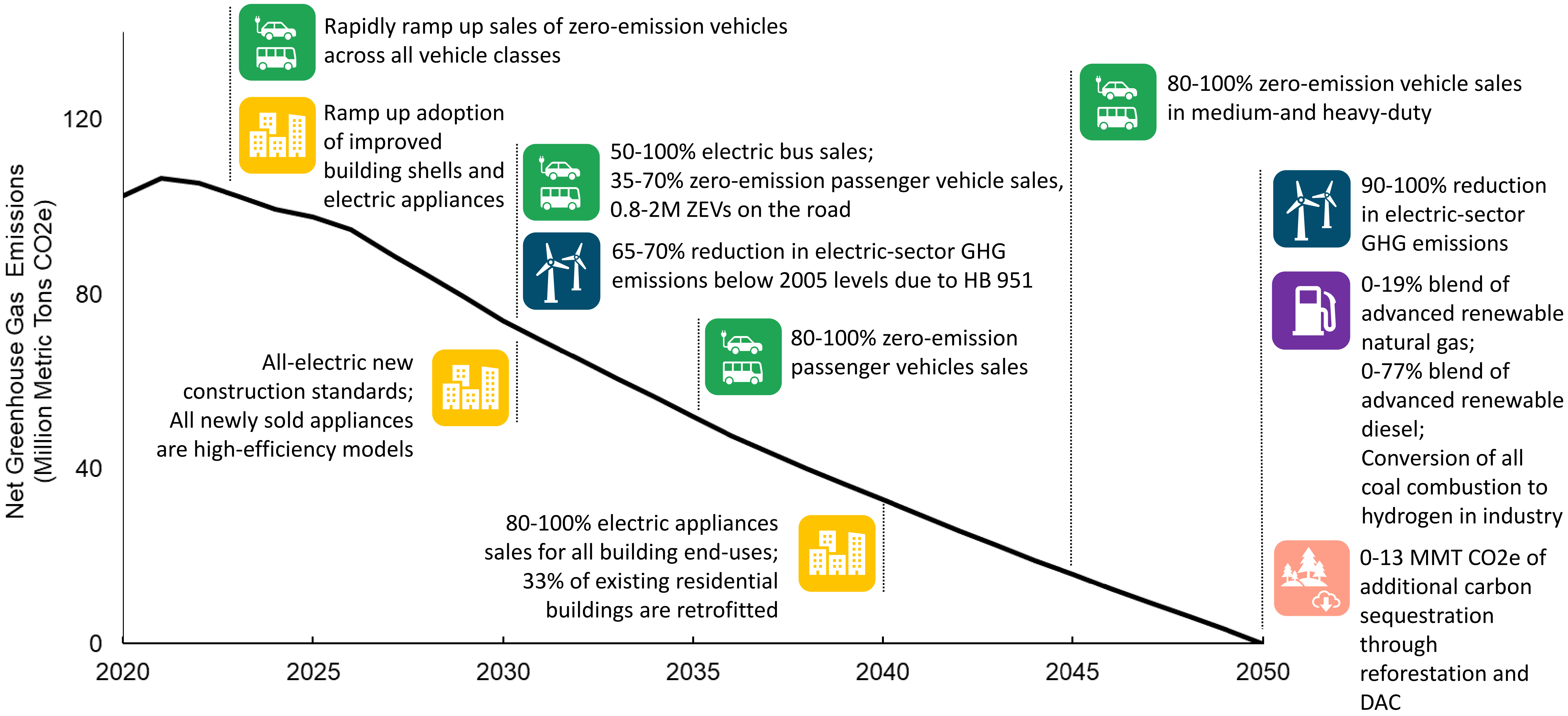
Decarbonized Fuels

- Production of advanced biofuels with sustainable biomass feedstocks
- Production of green hydrogen through electrolysis using renewable electricity

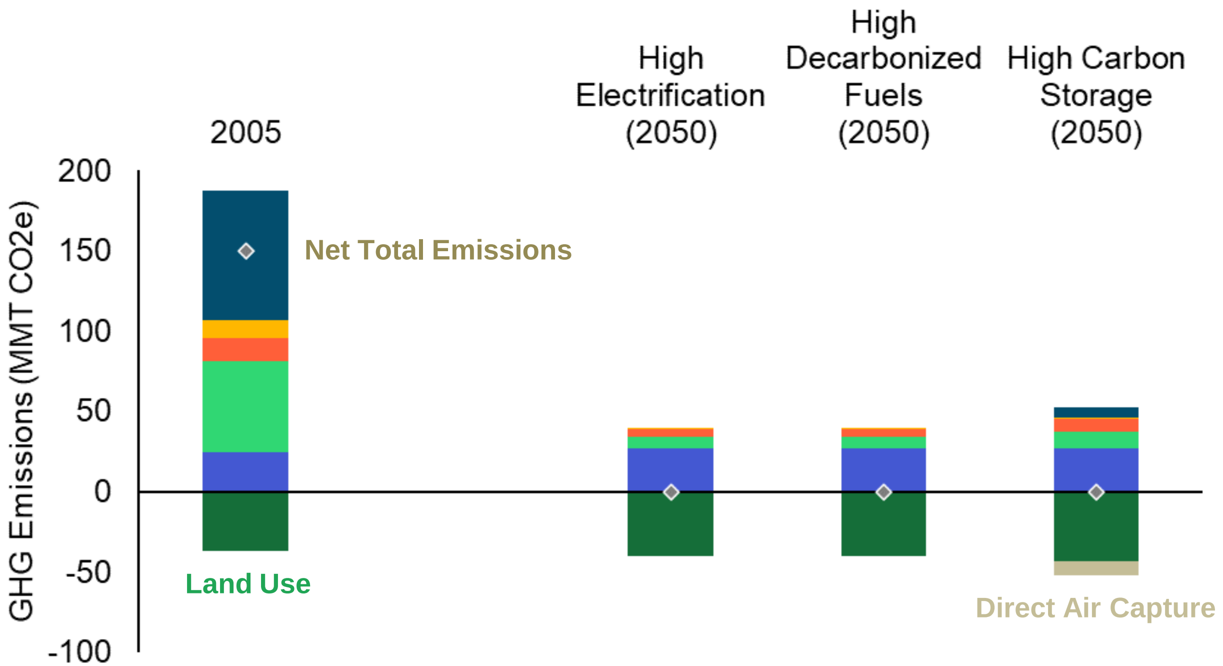
Carbon Sequestration

- Reforestation and restoration to enhance carbon sinks from natural and working lands
- Deployment of negative emissions technologies such as direct air capture of CO2 (DAC)

North Carolina Greenhouse Gas Emissions Reduction Measures Net Zero Scenario Ranges



Remaining Emissions in 2050 by Scenario



2050 % gross GHG emissions reductions by sector vs 2005	Size of sector in 2005 [MMT CO2e]	High Electrification	High Decarbonized Fuels	High Carbon Storage
Electric Power	80	100%	100%	92%
Buildings	12	94%	92%	90%
Industrial	14	64%	65%	47%
Transportation	57	88%	88%	82%
Non-Energy	24	-12%		

- **All mitigation scenarios meet net zero GHG emissions by 2050**
  - Gross (positive) emissions are reduced by 75-80% relative to 2005 in mitigation scenarios by 2050
  - NC's large natural carbon sinks are enough to offset the remaining gross emissions in all scenarios except for High Carbon Storage, where additional 9 MMT CO2e sequestration from direct air capture (DAC) is required to achieve net zero
- **The most reductions are coming from the electricity generation, transportation, and buildings sectors.**
- **Largest remaining sources of emissions are non-energy, non-combustion sectors like agriculture and waste*, followed by hard to decarbonize sectors like industry and transportation**
  - Most remaining transportation emissions are from aviation and remaining diesel trucks that have not yet been retired

* Footnote: waste emissions increase based on the annual growth rate used in the 2022 NC GHG Inventory projection through 2030, with a small reduction (15%) relative to Reference in 2050 based on the technical potential modeled by EPA in their state-level assessment

There are multiple pathways to meeting the NC's 2030 and 2050 climate targets.

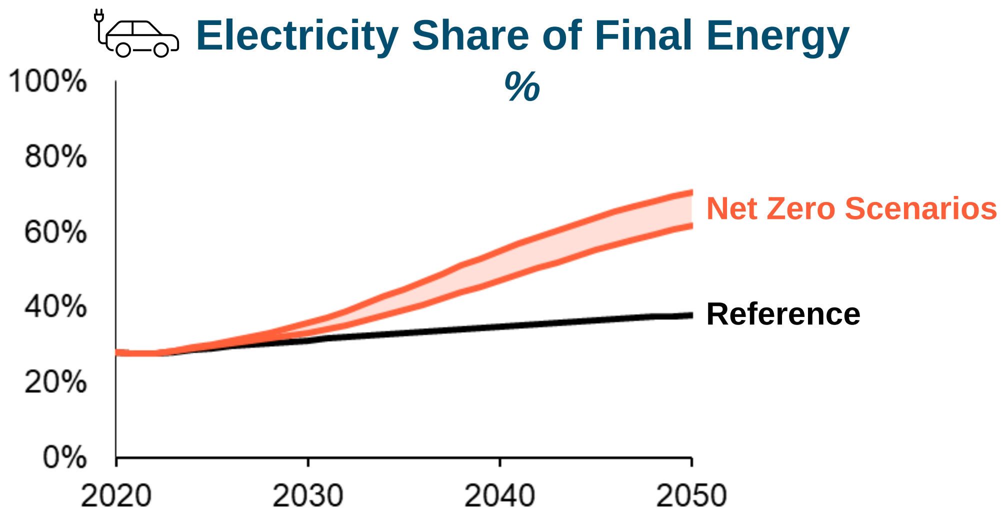
+ The commonalities across all scenarios represent near-term opportunities for "no-regret" actions:

1. Accelerate a **transition to zero-emission vehicles and electric heat pumps** in buildings
2. Rapidly **decarbonize electricity generation** by scaling up renewable electricity sources and battery storage
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
4. Support commercialization of **decarbonized fuels**, at a minimum to green hydrogen for industry and large trucks, and exploring pilots for advanced biofuels using sustainable biomass feedstocks
5. Reduce **non-energy GHG emissions** from industry, agriculture, waste, and oil and gas systems
6. Prioritize **sustainable management of natural and working lands** to enhance the critical role of carbon sequestration in helping achieve net zero emissions
7. Center **environmental justice and equity** in program design and local implementation

Summary of Preliminary Findings – 1/4

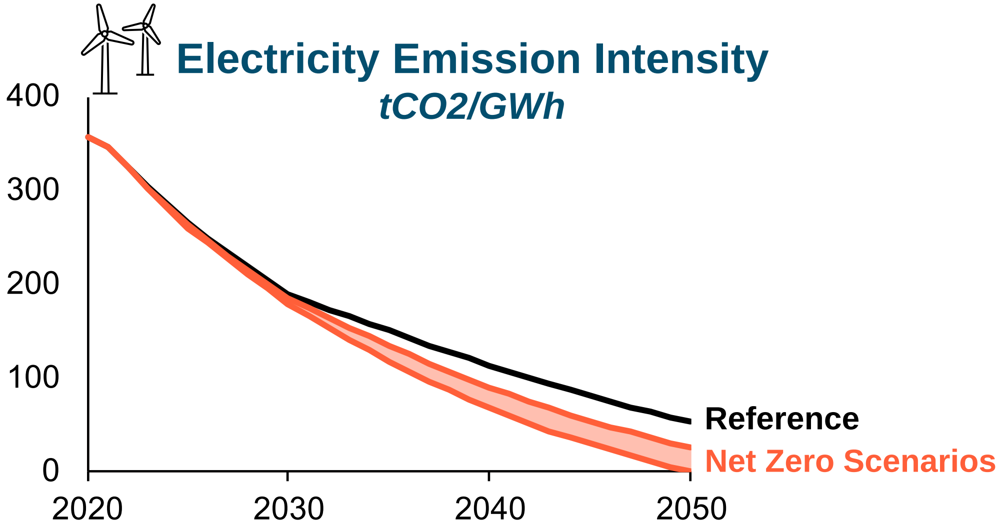
1 **Accelerate electrification of transportation** (zero-emission vehicles) **and buildings** (heat pumps, electric cooktops, etc.)

- Electricity becomes the foremost fuel powering the economy, meeting 60%-70% of all energy demand



2 **Rapidly decarbonize electricity generation** by scaling up renewable electricity sources and battery storage

- Emissions intensity of electricity generation decreases by 93%-100% by 2050



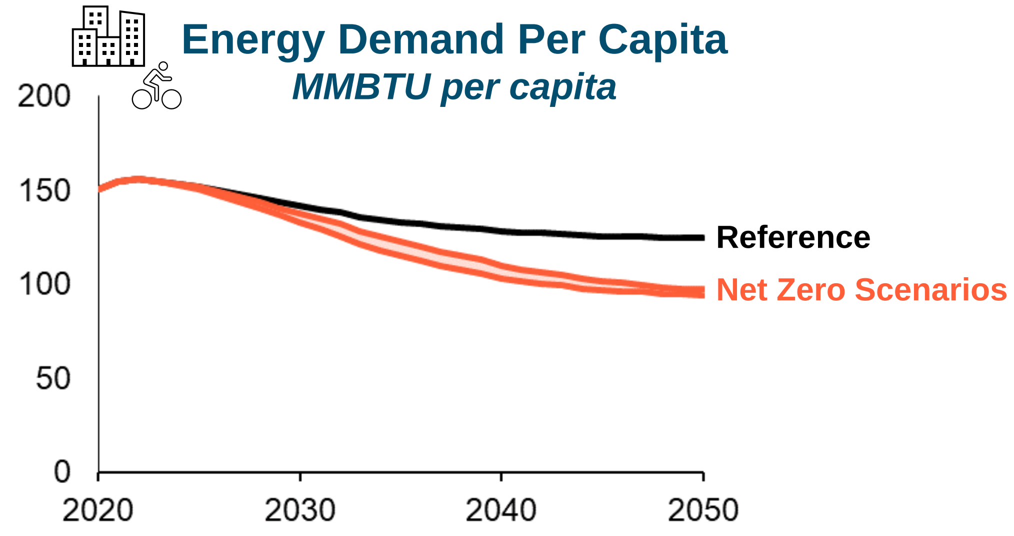
Summary of Preliminary Findings – 2/4

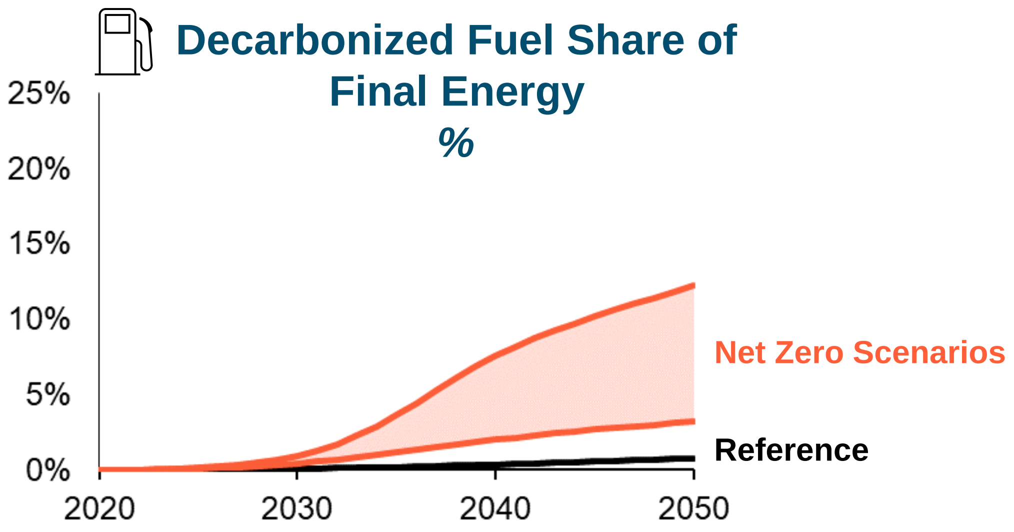
3 **Encourage high levels of energy efficiency**, such as adoption of efficient appliances and vehicles, improvement of building shells, and reduction in VMT

- Energy use per capita decreases by ~45% by 2050, while meeting the same services
- Electric vehicles and heat pumps can be 3-4x as efficient as current fossil-powered options

4 **Support commercialization of decarbonized fuels,** at a minimum to green hydrogen for industry and large trucks, but also potential for advanced biofuels using sustainable biomass feedstocks

- Decarbonized fuels serve a critical but targeted role for hard-to-electrify sectors, reaching 3%-12% of energy demand

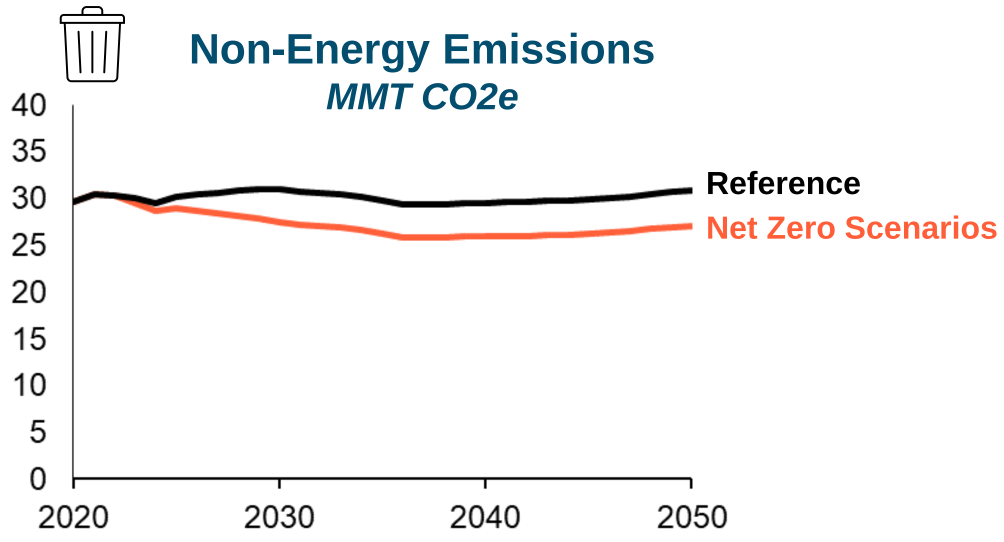




Summary of Preliminary Findings – 3/4

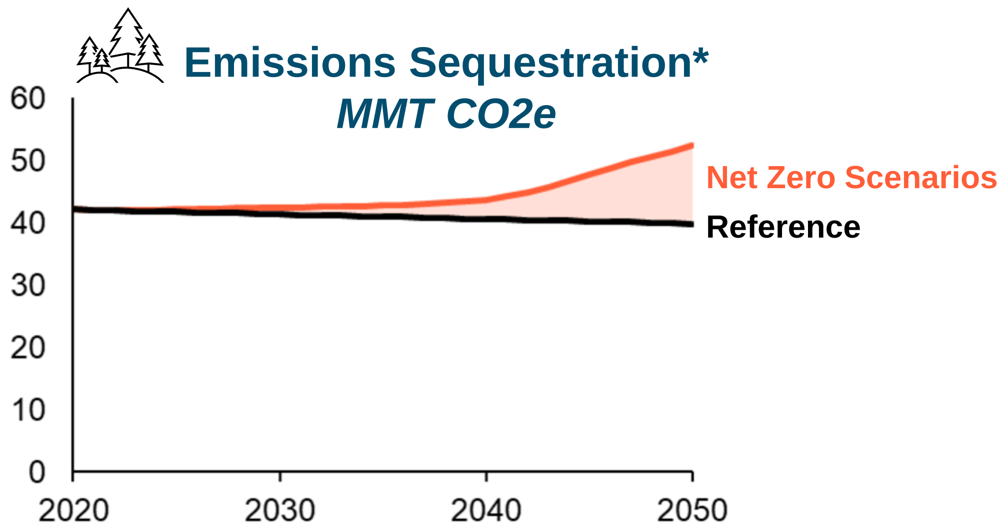
5 **Implement strategies to reduce non-energy greenhouse gas emissions** from industry, agriculture, waste, and oil and gas systems

- These sectors are some of the most challenging to mitigate at reasonable costs, but can achieve 12% reductions in 2050 vs. the Reference trajectory



6 **Prioritize sustainable management of natural and working lands** to enhance the critical role of carbon sequestration in helping achieve net zero emissions

- North Carolina's natural carbon sink plays a critical role and when combined with Direct Air Capture can lead to an additional 10 MMT of annual sequestration in 2050

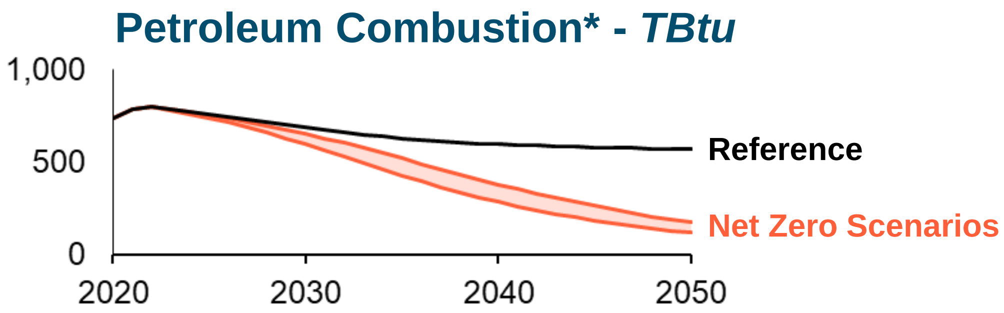


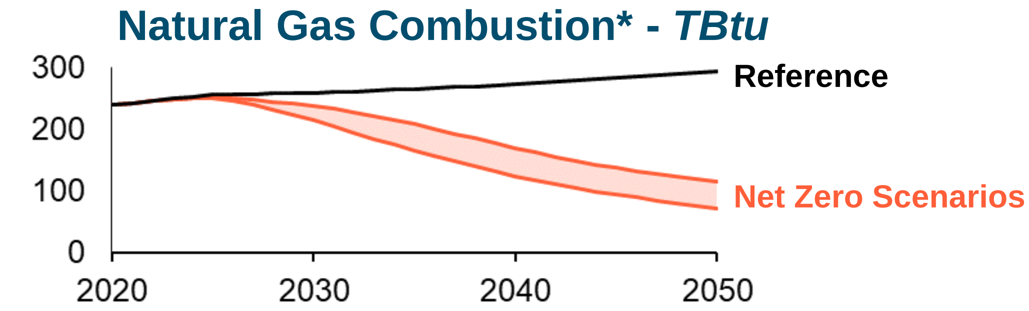
*Includes emission sequestration from natural and working lands, as well as negative emission technologies such as Direct Air Capture (DAC)

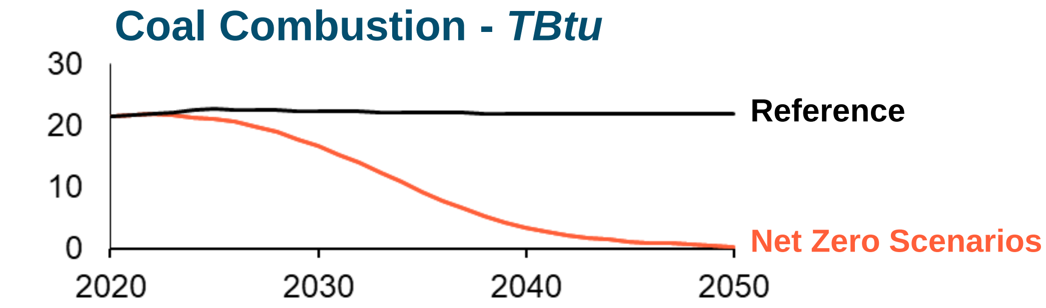
Summary of Preliminary Findings – 4/4

7 **Center environmental justice and equity** in program design and local implementation. This analysis focuses on *statewide* emissions, but highlights key opportunities:

- Improving air quality by reducing fuel combustion
  - Petroleum combustion is reduced ~80% by 2050 vs. today, natural gas combustion is reduced 50-70%, and coal combustion in industry is reduced by 100%
- Ensuring new technologies are affordable, especially electric vehicles and electric heat pumps
- Creating an accessible electric vehicle charging and transit network, prioritizing underserved areas and maximizing local air quality benefits in communities that have a disproportionate share of fuel combustion impacts







*Renewable petroleum and renewable natural gas are included in combustion totals due to similar air pollution impacts of these fuels

How can you stay engaged?

- **Feedback is welcome:**
  - What do you think about the draft decarbonization scenarios?
  - What concerns do you have and what challenges do you expect in North Carolina reaching the climate goals?
  - What additional considerations would you recommend for the NC Pathways Analysis?
  - *Feedback can be submitted by October 31st* to contactgov@nc.gov
  - *Website to stay up to speed on the Pathways and learn more: https://governor.nc.gov/issues/environment*
- **Next Steps:**
  - E3 will finalize the mitigation scenarios
  - E3 will present final mitigation scenario results at the next public meeting (TBD in December)

Appendix

Energy+Environmental Economics

Members of the Technical Advisory Group

Academic Research

- Brian Murray- Interim Director, Nicholas Institute and Duke University Energy Initiative
- Jeremiah Johnson- Associate Professor, NC State University
- Robert Cox- Associate Director, UNC Charlotte Energy Production and Infrastructure Center

Power Sector

- Mark McIntire- Director of Government Affairs, Energy and the Environment and Stakeholder Engagement, Duke Energy
- Michael Youth- Government and Regulatory Affairs Counsel, North Carolina's Electric Cooperatives
- Ward Lenz- Executive Director, NC Sustainable Energy Association

Transportation Sector

- Catherine Kummer- Sustainability, Resiliency and Governmental Affairs Officer, Charlotte Area Transit System
- Heather Brutz- Transportation Finance and Operations Manager, NC Clean Energy Technology Center

Residential, Commercial, and Industrial

- Kevin Martin- Executive Director, Carolina Utility Customers Association
- Ross Smith- President, NC Manufacturers Alliance
- Thomas Phoenix- Principal, CPL Architects and Engineers

Land Use, Land-Use Change and Forestry

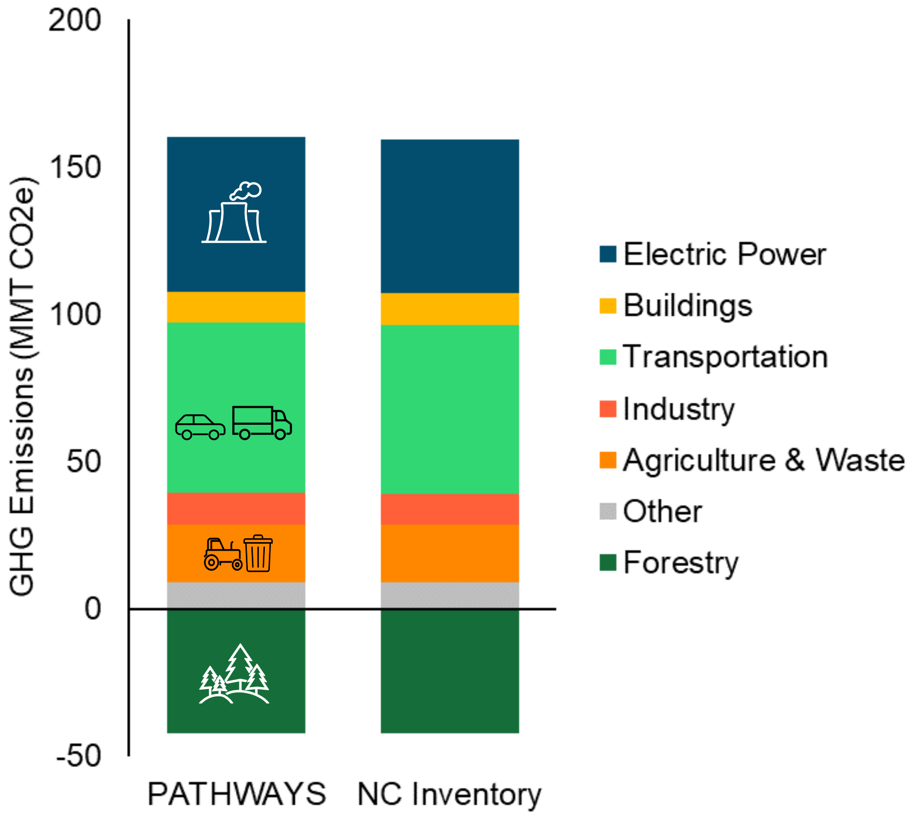
- Justin Baker- Associate Professor, NC State University
- Lydia Olander- Director of the Ecosystem Services Program, Duke University

Public Interest

- Al Ripley- Director, Consumer, Housing & Energy Project, NC Justice Center
- Amanda Levin- Interim Director of Policy Analysis, Natural Resources Defense Council
- Sherri White-Williamson- Environmental Justice Policy Director, NC Conservation Network

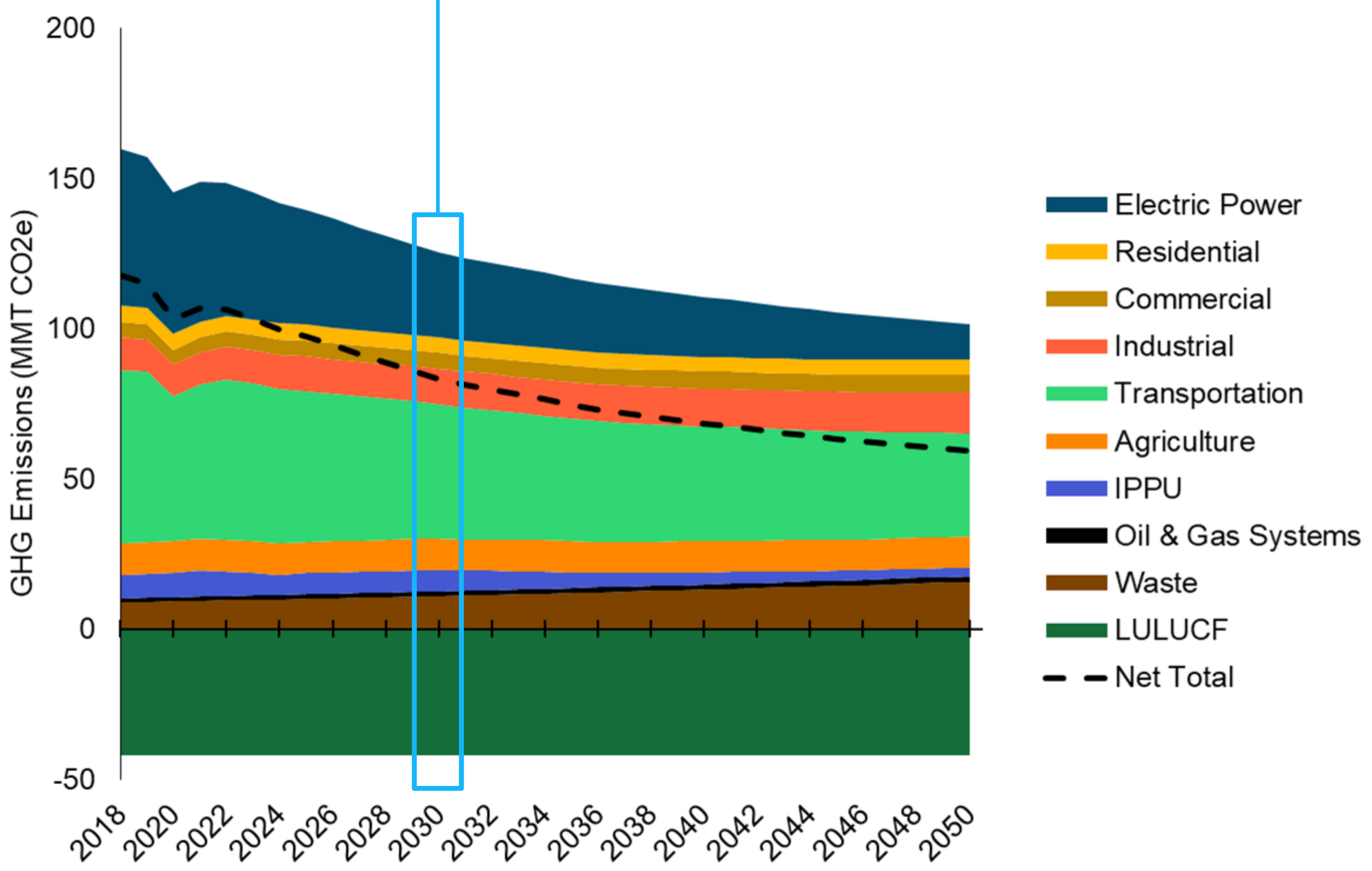
Benchmarking with NC Greenhouse Gas (GHG) Inventory

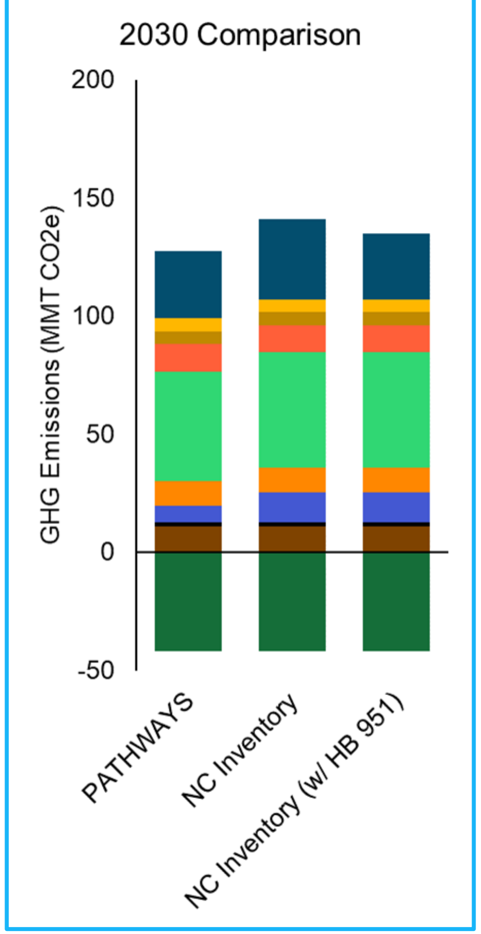
Base Year 2018 GHG Emissions Comparison



- **The NC PATHWAYS model is fully benchmarked to the latest NC State GHG Inventory (*released January 2022 by the NC Department of Environmental Quality*)**
  - Both *GHG emissions* and *final energy demand* are consistent with the analysis supporting the NC GHG Inventory
- **Total emissions in PATHWAYS are within <1% of NC Inventory**

Reference Scenario Draft Results: GHG Emissions by Sector





2030 Emissions Deltas

(PATHWAYS minus NC Inventory with HB 951)

Sector	MMT CO_2e*
Electric Power	0
Residential	0
Commercial	0
Industrial	1
Transportation	-4
Agriculture	0
IPPU	-5
Oil & Gas	0
Waste	0
LULUCF	0
Net Total	-8

**Rounded to nearest 1 MMT CO_2e, totals may not sum to Net Total due to rounding*

Approach to IRA Inclusion in NC PATHWAYS

+ **The Inflation Reduction Act contains many provisions that will impact energy and technology costs across virtually all sectors of the economy over the coming years;**
  - However, early external analyses provide only high-level estimates of national impacts
+ **Upon discussion with the Governor's Office, E3 is modeling our own assumptions on IRA impacts for key demand-side sectors/technologies (details in appendix):**

Direct IRA Impacts Added to Reference	IRA Impacts Not Explicitly Added
• Adoption of **residential heat pumps** • Adoption of **zero-emission medium-heavy-duty vehicles** • **Hydrogen fuel-switching**	• **Clean electricity generation -** HB 951 is already modeled with deep reductions in electricity sector emissions and there is no detailed electric sector modeling included in this project • Adoption of **zero-emission light-duty vehicles -** there is a lot of uncertainty with eligibility for the new EV tax incentives and our initial analysis showed a likely small impact relative to current assumptions • **Industry CCS incentives and methane fee –** there is almost no eligible industry and activity in NC • Important to narratively highlight that IRA provisions will make existing electricity sector decarbonization requirements in North Carolina more cost-effective along with many other decarbonization measures

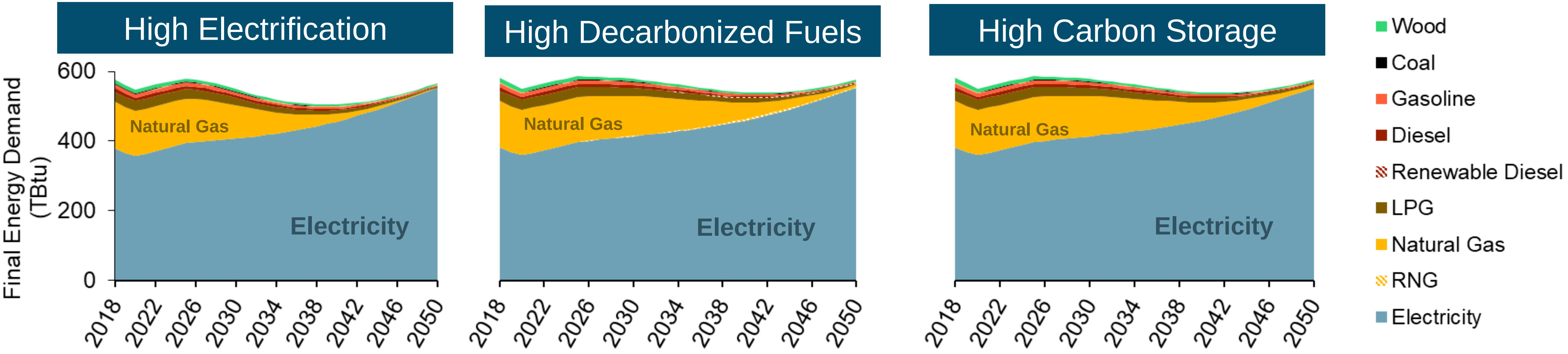
NC PATHWAYS Key Drivers

Sector	Key Driver for Underlying Growth	Key Driver Annual Growth Rate	Key Driver Source
Residential	Households	1.6%	NC Office of State Budget and Management & U.S. Energy Information Administration (EIA) Annual Energy Outlook 2022
Commercial	Commercial Sq. Footage	1.0%	EIA Annual Energy Outlook 2022
Transportation	VMT*	0.8% *(avg across vehicle classes)*	NC Department of Environmental Quality Motor Vehicle Emission Simulator 3 (MOVES3) modeling used for NC Greenhouse gas (GHG) Inventory
Industrial	Industrial Fuel Use	Varies by Fuel	EIA Annual Energy Outlook 2022
Non-Energy, Non-Combustion (incl. Agriculture, Waste, Industrial Processes & Product Uses)	Direct GHG Emissions	Varies by Gas/Source	NC GHG Inventory Projection
Land-Use, Land-Use Change, and Forestry (LULUCF)	Annual CO_2 flux	TBD	Currently held constant at 2018 levels per NC GHG Inventory Projection
Electricity Generation**	Annual load growth	TBD	Bottom-up estimates from assumptions in buildings, transportation, and industry

**VMT reported here as average, but individual growth rates are used for each vehicle type in PATHWAYS (e.g., Light Duty Cars, Medium and Heavy Duty Trucks, Buses)*
***Detailed electricity generation modeling not included in this analysis*

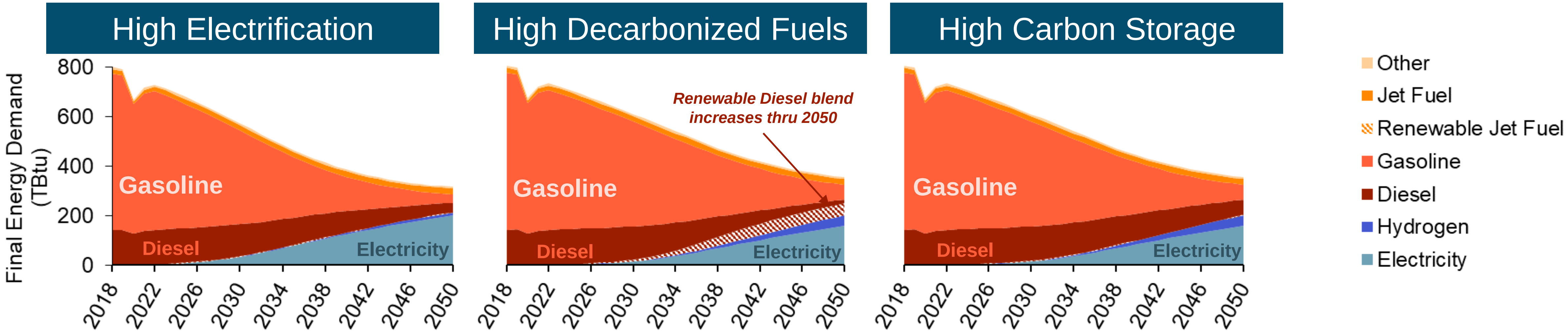
Net Zero Scenarios Key Assumptions and Results Buildings

Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
Energy Efficiency	• All newly sold appliances are high efficiency models by 2030 • Adoption of latest IECC 2021 building code for new construction • One-third of existing residential buildings are retrofitted by 2040 (based on ACEEE NC report)		
Electrification	• All-electric new construction standard by **2030** • 100% sales of electrified devices for all end uses (space and water heating, drying, cooking) by **2040**	• All-electric new construction standard by **2040** • 100% sales of electrified devices for all end uses (space and water heating, drying, cooking) by **2045,** with some sales of hybrid heat pumps for homes that have existing gas furnaces	
Renewable Natural Gas	None	**18% RNG blend** by 2050	None



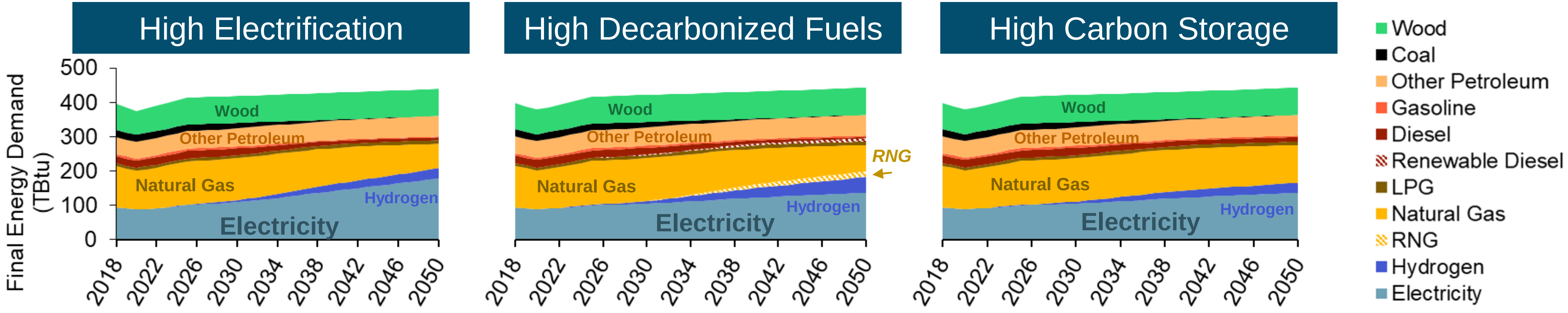
Net Zero Scenarios Key Assumptions and Results Transportation

Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
VMT Reductions	1.2% reduction in statewide VMT below BAU levels by 2040 based on NC DOT VMT Reduction Study		
LDV ZEVs	100% ZEV sales by **2035**	100% ZEV sales by **2045**	
MHDV ZEVs	100% ZEV sales by **2045** (90/10 split for BEV/HFCV)	100% ZEV sales by **2050** (75/25 split for BEV/HFCV)	
Off-road Gasoline and Diesel Electrification	Electrify gasoline and diesel at same rate as MHDV	Electrify gasoline and diesel at same rate as MHDV	
Renewable Diesel	None	**77% renewable diesel blend** by 2050	None



Net Zero Scenarios Key Assumptions and Results Industry

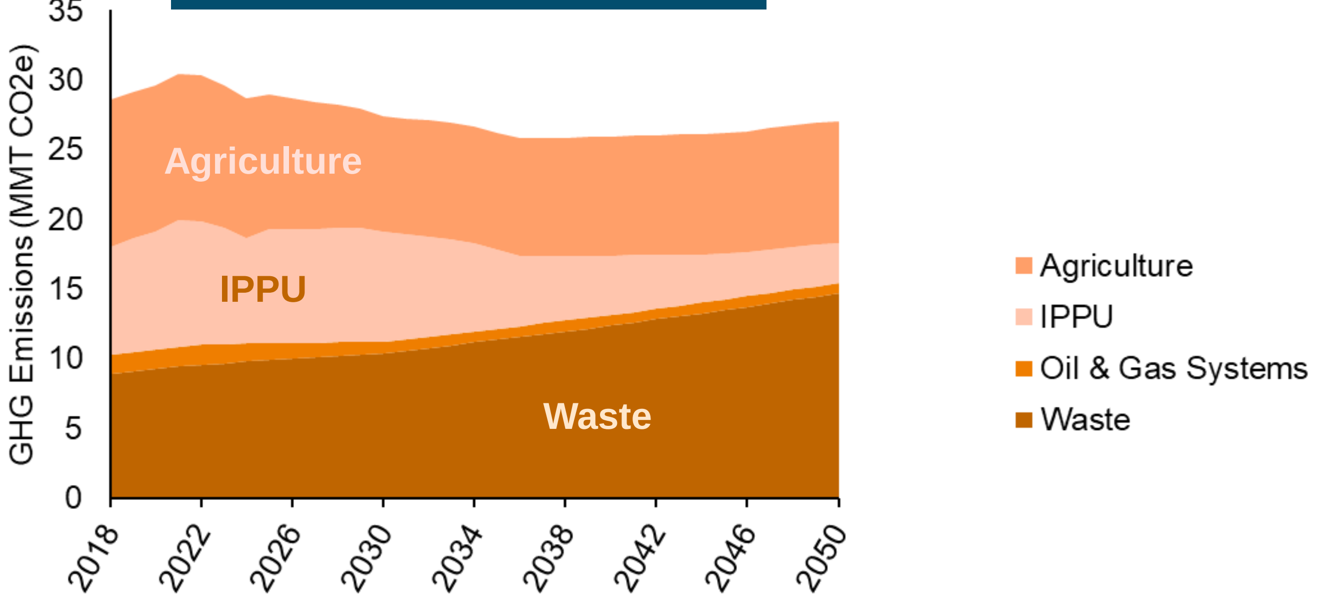
Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
Manufacturing Energy Efficiency	16% reduction in manufacturing energy demand through efficiency by 2050 based on ACEEE Halfway There report		
Natural Gas Electrification	Electrify natural gas use for process heat based on NREL Electrification Futures Study **High Electrification scenario**	Electrify natural gas use for process heat based on NREL Electrification Futures Study **Medium Electrification scenario**	
Liquid Fuels Electrification	Electrify gasoline and diesel at same rate as MHDV	Electrify gasoline and diesel at same rate as MHDV	
H2 Fuel-switching	**9% of natural gas and all coal** is converted to H2 combustion by 2050	**22% of natural gas and all coal** is converted to H2 combustion by 2050	**9% of natural gas and all coal** is converted to H2 combustion by 2050
Advanced Biofuels	None	**18% renewable natural gas blend** and **77% renewable diesel blend** by 2050	None



Net Zero Scenarios Key Assumptions and Results
Non-energy & non-combustion

Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
Waste Management Methane Reductions	Reductions available below \$100/tCO2e from 2019 EPA Non-CO2 Report (e.g., landfill gas recovery), results in ~10% reduction below BAU by 2050		
Agriculture Methane and N2O Reductions	Reductions available below \$100/tCO2e from 2019 EPA Non-CO2 Report (e.g., manure methane recovery, nitrogenous fertilizer management), results in ~20% reduction below BAU by 2050		
IPPU: HFC Phasedown	HFC phasedown in line with new EPA HFC Allowance Allocation and Trading Program, results in 63% reduction in IPPU emissions below 2018 levels by 2050 (also included in Reference Scenario)		

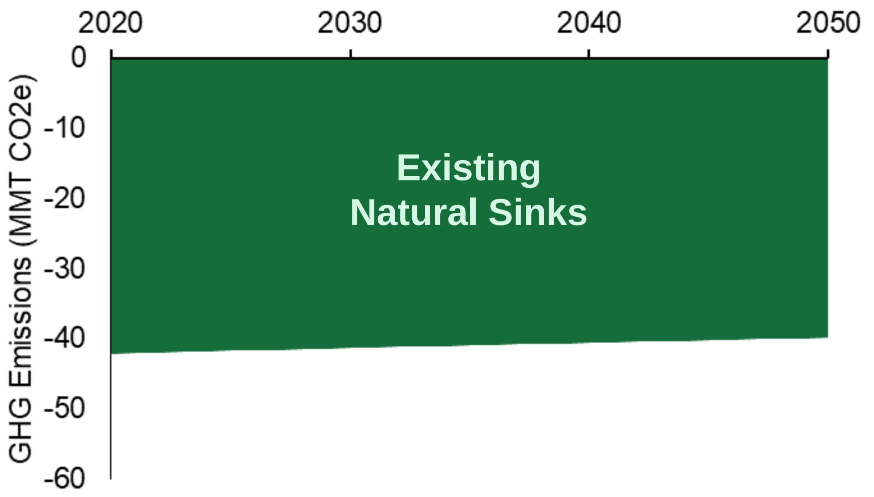
All Net Zero Scenarios



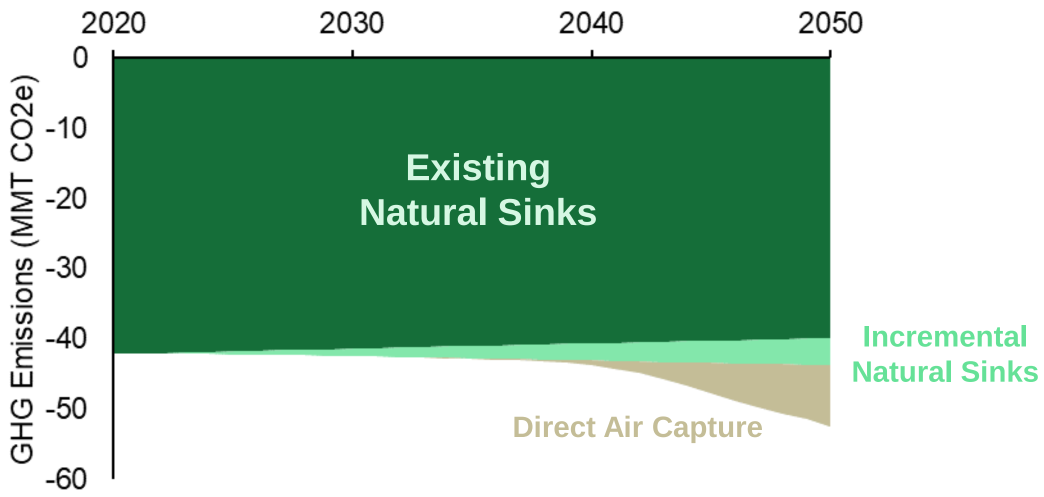
Net Zero Scenarios Key Assumptions and Results
Carbon Sequestration

Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
Land Use and Land Use Change and Forestry (LULUCF)	Existing sequestration declines slightly over time due to projected loss of forests and sea level rise impacts (~2.5 MMT CO2e reduction in net sequestration by 2050)		~4 MMT CO2e of incremental sequestration beyond Reference scenario levels in 2050 due to reforestation and restoration of saline tidal flows
Negative-Emissions Technologies (NETs)	None required	None required	~9 MMT of DAC required to achieve net zero

High Electrification / High Decarbonized Fuels



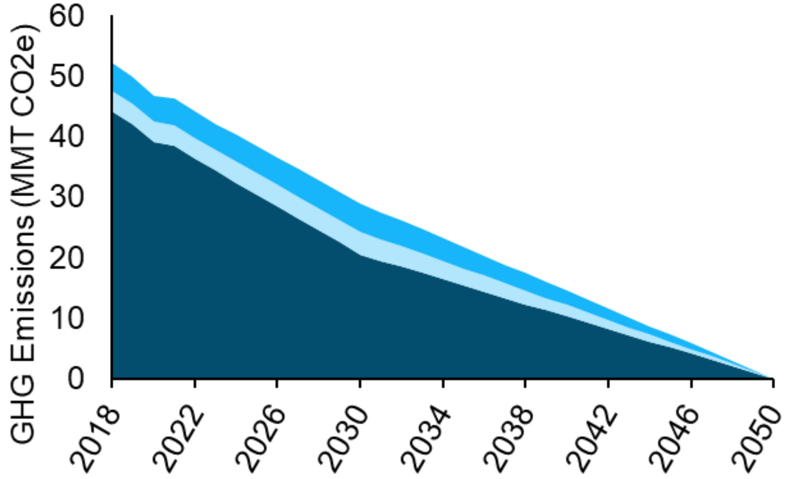
High Carbon Storage



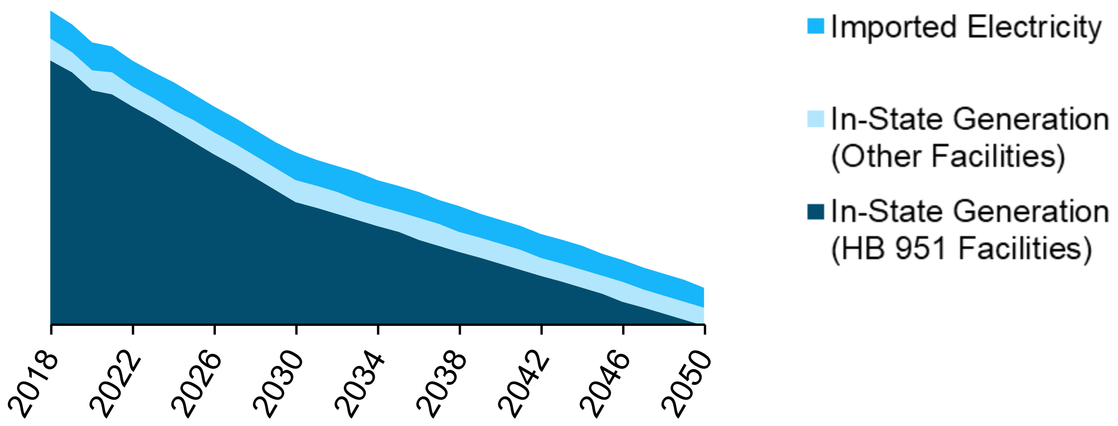
Net Zero Scenarios Key Assumptions and Results Electricity Generation

Measure	High Electrification	High Decarbonized Fuels	High Carbon Storage
Clean Electricity	70% reduction in emissions by 2030, 100% by 2050 (**HB 951 reduction levels but for all sources**, not just IOU sources)		70% reduction in emissions by 2030, 100% by 2050 **for IOU sources only** Non-IOU sources and imports have a 51% reduction in emissions intensity by 2050 based on EIA Reference Case

High Electrification / High Decarbonized Fuels



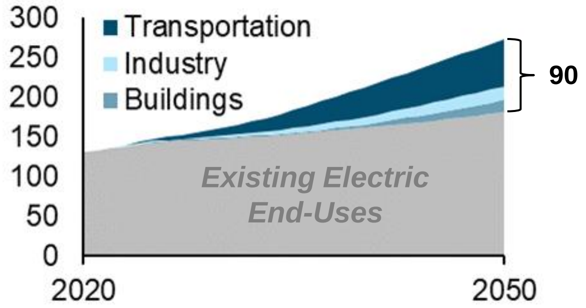
High Carbon Storage

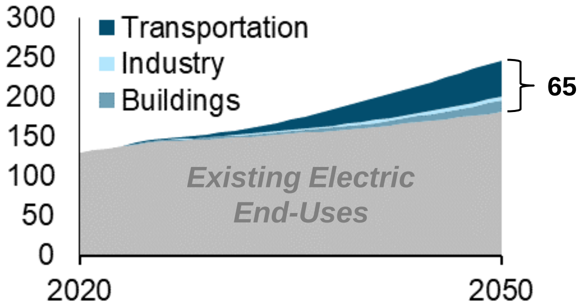


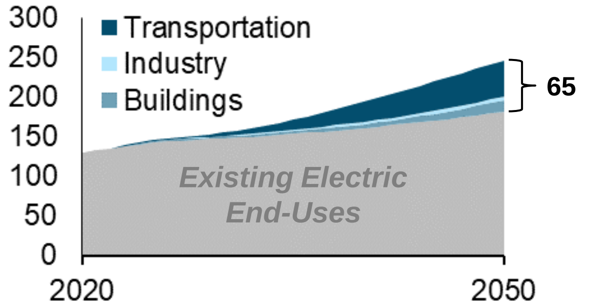
Key Metrics by Scenario

High Electrification | High Decarbonized Fuels | High Carbon Storage

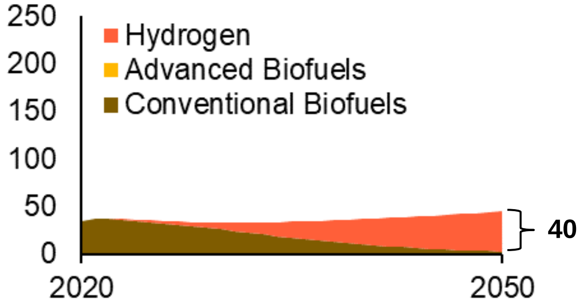
Electricity Demand (TWh)

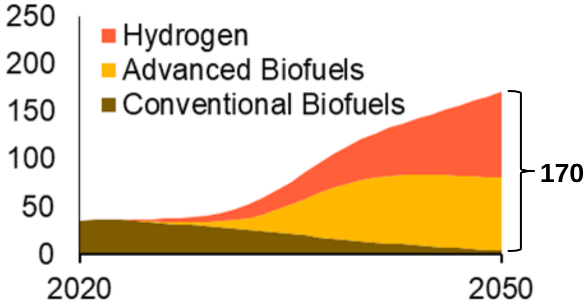


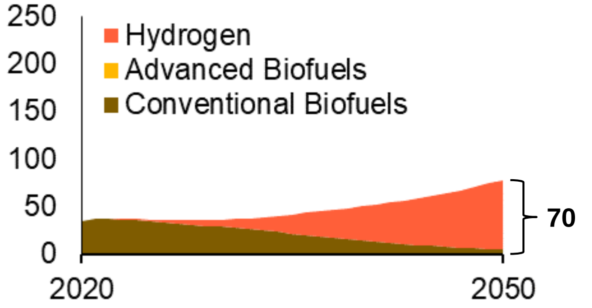




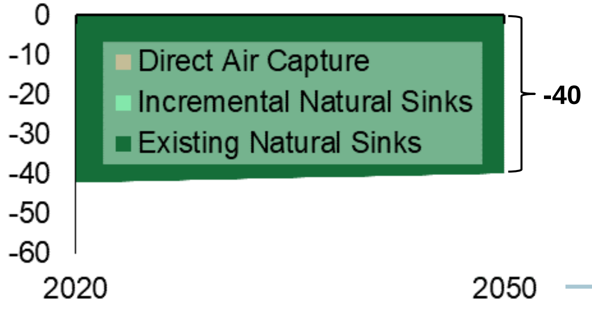
Decarbonized Fuel Demand (TBtu)

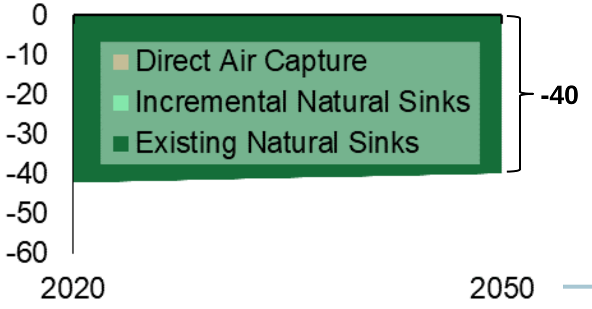


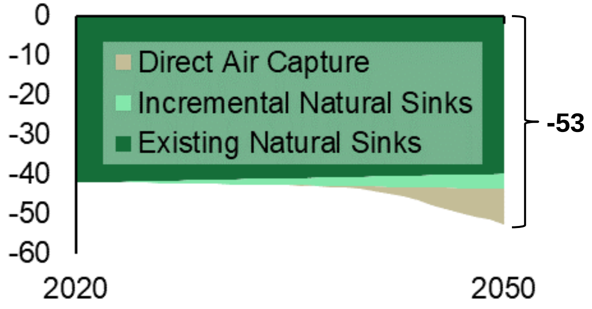




Carbon Sequestration (MMT CO2)







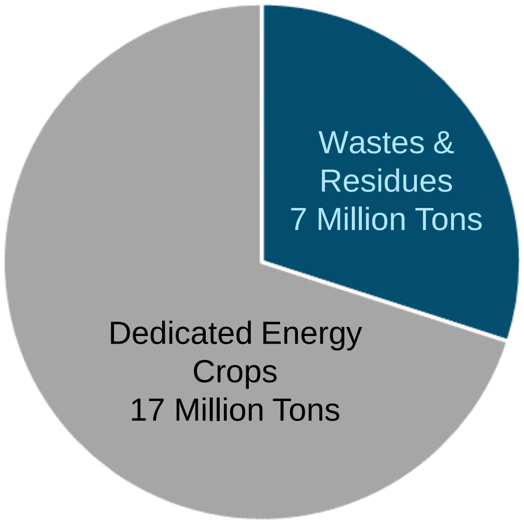
Advanced Biofuels Overview

- One strategy for reducing GHG emissions in PATHWAYS scenarios is to replace fossil fuels with advanced biofuels, which are assumed to be carbon-neutral and chemically identical to fossil fuels
- These advanced biofuels are distinct from conventional biofuels like ethanol and biodiesel, which have sustainability concerns in terms of lifecycle GHG emissions and have blend limits due to being chemically different from fossil fuels
- Despite advance biofuels being treated as carbon-neutral when it comes to GHG emissions in PATHWAYS, there are other important considerations for their use, including:
  - **Air pollution** – advanced biofuels produce similar levels of criteria air pollutants as fossil fuels
  - **Market development** – advanced biofuels production is very limited today, with most biofuels markets focused on conventional biofuels
  - **Land use and other sustainability concerns** – growing biomass specifically for use in advanced biofuels could potentially displace land used for food production or other economic needs, and the energy required to produce advanced biofuels could potentially come from fossil fuels
- Because of these factors, we typically assume that advanced biofuels will play a targeted role in any net zero future and are best used for applications where electrification or other decarbonization strategies are challenging (e.g., as renewable jet fuel for airplanes)

Biofuels Sustainability Screening

- To estimate what feedstocks will be available in the future for processing into advanced biofuels, E3 relies on the 2016 Billion Ton Report from the Department of Energy
- The feedstocks quantified in the Billion Ton Report can be grouped into two broad categories:
    1. **Wastes and residues** that are byproducts of existing agricultural practices or economic activities and require no additional agronomic inputs such as land or fertilizer (e.g., manure, landfills, forest thinning)
    2. **Dedicated energy crops** that are grown primarily for conversion into fuel and require additional cultivation of land that would otherwise not occur
- In the PATHWAYS scenarios developed for North Carolina, E3 chose to only consider wastes and residues due to sustainability concerns around the lifecycle GHG emissions of dedicated energy crops
    - Note: This climate sustainability screening does not consider other potentially important criteria, such as local pollution impacts of agricultural practices or economic activities.

Estimated 2050 Biofuel Feedstocks in NC

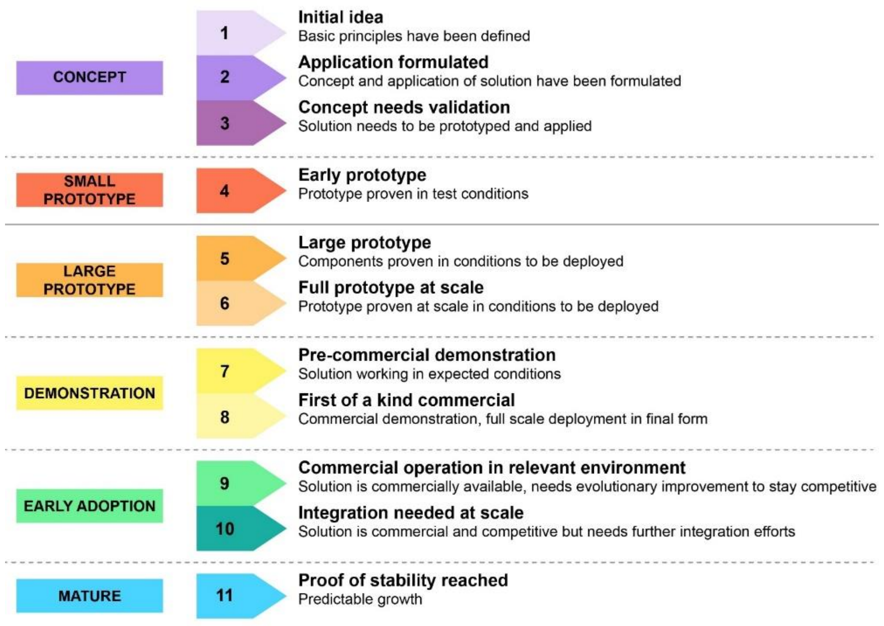


Technology Readiness & Risks

Identifying Risks in an Uncertain Future

+ **Developing scenarios across a 30-year time horizon includes many uncertainties and risks, including:**
  - Customer adoption risk
    - Widespread adoption of zero-emission vehicles will require affordable model options, accessible charging infrastructure, and large-scale technology acceptance
  - Commercialization risk
    - Decarbonization scenarios rely on technologies with varying levels of commercialization, or readiness.
    - IEA has established a Technology Readiness Level (TRL) scale for decarbonization measures.
    - A technology with a TRL of 11 is ready to scale, options lower than that need R&D and/or commercialization support.
    - Portfolios of decarbonization options that rely on lower TRL measures carry additional risk.
    - E3 and other deep decarbonization researchers generally screen out technologies that are low (<5) on the TRL scale because of their speculative nature and the short time horizon of mid-century climate goals.

Commercialization Risk through TRLs



Credit: International Energy Agency

Technology Readiness & Risks

		Today's TRL	Expected timing of technology ramp-up in scenarios (2020 / 2030 / 2040 / 2050)
Electric Appliances in Buildings Air-source heat pumps (ASHPs) in all scenarios	ASHPs for Res/Small Commercial	10	
	ASHPs for Large Commercial	8	
Zero-Emission Vehicles Zero-emission light-duty vehicles (LDVs) and zero-emission medium-and-heavy-duty vehicles (MHDVs) in all scenarios	Battery-electric LDVs	9	
	Battery-electric MHDVs	8	
	Hydrogen Fuel-cell MHDVs	7	
Renewable Electricity In all scenarios	Solar PV, wind and grid-scale Li-ion battery storage	9 - 10	
Decarbonized Fuels Green hydrogen In all scenarios for hydrogen fuel-cell vehicles and industry; renewable natural gas (RNG) and renewable diesel in High Decarbonized Fuels scenario	Green Hydrogen through alkaline electrolysis	9	
	RNG through bio-gasification	8	
	Renewable diesel through pyrolysis	7	
Negative Emissions Technologies In the High Carbon Storage scenario	Direct air capture	7	

Footnote: TRLs are based on values from an IEA database, modified in some cases by E3 based on our professional judgement, including an assessment of geographic context.