NOACA
Northeast Ohio Areawide Coordinating Agency

CITY OF CLEVELAND
Mayor Justin M. Bibb
MAYOR'S OFFICE OF SUSTAINABILITY

CLEVELAND-ELYRIA METROPOLITAN STATISTICAL AREA COMPREHENSIVE CLIMATE ACTION PLAN

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PREPARED FOR:
Climate Pollution Reduction Grant Program
U.S. Environmental Protection Agency

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List of Acronyms

- AFOLU: Agriculture, Forestry, and Other Land Uses
- ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
- BAU: Business As Usual
- BESS: Battery Energy Storage Systems
- BEVs: Battery Electric Vehicles
- BF-BOF: Blast Furnace-Basic Oxygen Furnace
- BLS: U.S. Bureau of Labor Statistics
- BRT: Bus Rapid Transit
- CAFE: Corporate Average Fuel Economy
- CAP: Climate Action Plan
- CBOs: Community-Based Organizations
- CCA: Community Choice Aggregation
- CCAP: Comprehensive Climate Action Plan
- CCUS: Carbon Capture, Sequestration, and Utilization
- CEJST: Climate and Economic Justice Screening Tool
- CH_4: Methane
- CHP: Combined Heat and Power
- CO_2: Carbon Dioxide
- COBRA: CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool
- C-PACE: Commercial Property Assessed Clean Energy
- CPP: Cleveland Public Power
- CPRG: Climate Pollution Reduction Grant
- CRDF: Cleveland Regional Decarbonization Framework Team
- CRVA: Climate Risk and Vulnerability Assessment
- CSU: Cleveland State University
- CTC: Cleveland Tree Coalition
- CVNP: Cuyahoga Valley National Park
- CWRU: Case Western Reserve University
- DAC: Direct Air Capture
- DERs: Distributed Energy Resources
- DOAS: Dedicated Outdoor Air Systems
- DOE: United States Department of Energy
- EAF: Electric Arc Furnace
- EER: Evolved Energy Research
- EJScreen: Environmental Justice Screening and Mapping Tool
- EVs: Electric Vehicles
- FBCs: Form-Based Codes
- FCVs: (Hydrogen) Fuel Cell Vehicles
- FLIGHT: Facility Level Information on Greenhouse Gases Tool
- GCRTA: Greater Cleveland Regional Transit Authority
- GDP: Gross Domestic Product
- GGRF: Greenhouse Gas Reduction Fund
- GHG: Greenhouse Gas
- GHGRP: Greenhouse Gas Reporting Program
- GO Bond: General Obligation Bond
- GPC: Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
- GW: Gigawatts
- GWP: Global Warming Potential
- H_2: Hydrogen
- H_2DRI: Hydrogen-Based Direct Reduction
- HEAT: Health Economic Assessment Tool
- HEEHRA: High-Efficiency Electric Home Rebate Act Program
- HFCs: Hydrofluorocarbons
- HOMES: Home Efficiency Rebates Program
- HVAC: Heating, Ventilation, and Air Conditioning

- IAC: Industrial Assessment Center
- ICEV: Internal Combustion Engine Vehicle
- IEA: International Energy Agency
- IHSC: Industrial Heartland Solar Coalition
- IIJA: Infrastructure Investment and Jobs Act
- IOU: Investor-Owned Utility
- IPCC: Intergovernmental Panel on Climate Change
- IPPU: Industrial Processes and Product Use
- IRA: Inflation Reduction Act
- ITC: Investment Tax Credit
- JCRP: Joel Ratner Community Partnership
- KSU: Kent State University
- kW: Kilowatt
- Lbs/MWh: Pounds per Megawatt Hour
- LCA: Life Cycle Analysis
- LDV: Light-Duty Vehicle
- LEED: Leadership in Energy and Environmental Design
- LIDAC: Low-Income and Disadvantaged Community
- LIHEAP: Low-Income Home Energy Assistance Program
- LISC: Local Initiatives Support Coalition
- LMI: Low- and Moderate-Income
- LOS: Level of Service
- Low-E: Low-Emissivity
- LTS: Level of Traffic Stress
- MHDVs: Medium- and Heavy-Duty Vehicles
- MMBtu: Million British Thermal Units
- $MMTCO_2e$: Million Metric Tons of CO_2 Equivalent Emissions
- MOE: Molten Oxide Electrolysis
- MOS: Mayor's Office of Sustainability and Climate Action (City of Cleveland)
- MPO: Metropolitan Planning Organization
- MSA: Metropolitan Statistical Area
- MT/Day: Metric Ton per Day
- $MTCO_2e$: Metric Ton of CO_2 Equivalent Emissions
- MW: Megawatts
- N_2O: Nitrous Oxide
- NAICS: North American Industry Classification System
- NCA: National Climate Assessment
- NDC: Nationally Determined Contribution
- NEI: National Emissions Inventory
- NEORSD: Northeast Ohio Regional Sewer District
- NEOSCC: Northeast Ohio Sustainable Communities Consortium
- NOACA: Northeast Ohio Areawide Coordinating Agency
- NOPEC: Northeast Ohio Public Energy Council
- NO_x: Nitrogen Oxides
- NREL: National Renewable Energy Laboratory
- O_3: Ozone
- ODOT: Ohio Department of Transportation
- OEC: Ohio Environmental Council
- P3: Public Purchasing Program
- PACE: Property Assessed Clean Energy
- PCAP: Priority Climate Action Plan
- PPA: Power Purchase Agreement
- PPB: Parts per Billion
- PTC: Production Tax Credits
- PUCO: Public Utilities Commission of Ohio
- PV: Photovoltaics (Solar)
- R&D: Research and Development
- RCP: Representative Concentration Pathways
- RDF: Regional Decarbonization Framework
- RNG: Renewable Natural Gas
- SAF: Sustainable Aviation Fuel

- SBT: Science-Based Target
- SBTN: Science-Based Targets Network
- SDSN: Sustainable Development Solutions Network
- SFA: Solar for All
- SI: EJScreen Supplemental Index
- SO_2: Sulfur Dioxide
- SOC: Soil Organic Carbon
- SOE: Solid Oxide Electrolyzer
- SOPEC: Sustainable Ohio Public Energy Council
- SOV: Single Occupant Vehicle
- SPA: Statistical Planning Area (City of Cleveland)
- SUN: Solar United Neighbors
- TCI: Transportation and Climate Initiative
- TCO: Total Cost of Ownership
- TDM: Transportation Demand Management
- TOD: Transit Oriented Development
- TOU: Time-of-Use (pricing)
- TW: Terawatt
- U.S. EIA: United States Energy Information Administration
- U.S. EPA: United States Environmental Protection Agency
- UHI: Urban Heat Island
- USDA: United States Department of Agriculture
- USGBC: United States Green Building Council
- VMT: Vehicle Miles Traveled
- VOC: Volatile Organic Compound
- VPP: Virtual Power Plant
- VRU: Vulnerable Road User
- WHO: World Health Organization
- WRLC: Western Reserve Land Conservancy
- ZEV: Zero Emissions Vehicle

Executive Summary

In 1970, Cleveland Mayor Carl Stokes told a United States (U.S.) Senate subcommittee that "We in Cleveland sit on the banks of a river and lake which become almost legendary, not only in the United States but abroad."[1] Mayor Stokes stood at the vanguard of an effort to convert a burning river into a movement against the devastating impact of human pollution on the nation's waterways, air quality, shared natural systems, and human health. Mayor Stokes understood that Northeast Ohio's common environmental challenges were intricately connected with other pressing problems, including housing, jobs, and poverty, and he recognized that these issues required regional solutions.[2]

More than 50 years later, the Cleveland-Elyria Metropolitan Statistical Area (MSA) faces another daunting environmental, economic, and social crisis from climate change. Addressing this challenge again requires us to recognize that our challenges are interconnected, and we must work collaboratively across sectors and jurisdictions.

This Comprehensive Climate Action Plan (CCAP) for the Cleveland-Elyria MSA builds upon the progress the region has already made to chart a path towards net zero emissions that will provide substantial co-benefits to residents and businesses. That progress includes the Priority Climate Action Plan (PCAP) and climate plans at the city and county levels.

This CCAP contains a review of greenhouse gas (GHG) emissions by sector (Chapter 2); regional GHG targets for 2030 and 2050 (Chapter 3); a discussion of climate changes already underway and the expected changes through 2050 (Chapter 4); a review of the costs of inaction (Chapters 5-6); the measures that MSA communities, organizations, and businesses can take to lower those emissions by 2050 (Chapter 7); an overview of the plan's benefits (Chapters 8-9); a review of the region's ability to implement and pay for actions (Chapters 10-11); an assessment of the workforce development needs to implement the plan (Chapter 12); a plan to help communities across the MSA implement such measures (CCAP Implementation Playbook); and additional technical appendices.

While communities and organizations across the MSA have taken significant steps to advance climate action, real challenges remain. Support for climate action is uneven across the region, and this lack of consensus makes regional or multi-community approaches difficult. The Cleveland-Elyria MSA is home to several vital legacy industries that account for a large share of climate pollution emissions in the MSA, and it will require significant resources to decarbonize their operations. Many communities also contain aging and inefficient housing stocks, face sprawling development patterns that limit transportation choice, and may struggle to access the resources necessary to invest in climate action, particularly with limited funding from the state and federal governments.

The Cleveland-Elyria MSA can once again lead the way towards net zero emissions, but reaching this goal by 2050 will require leadership, planning, vision, and commitment of community resources. Communities should look to the public, non-profit, and private sectors for climate action partners and build off the success of stakeholders already committed to this challenge. Successful climate action requires real relationships with communities through regular exchanges in trusted environments and with trusted representatives. This approach can build mutual trust and create new, stronger ways for parties to exchange ideas and information.

This CCAP outlines measures that are accessible for all communities, no matter where they are on their path to protect air, land, water, and human health through climate action. It builds upon the existing work of the MSA's climate leaders, while providing on-ramps for communities that have begun or are about to begin their own journeys. Not all the measures in this CCAP apply to every community, and leaders should choose the measures that best address their unique needs. The CCAP presents the costs, benefits, and co-benefits of measures, such as improved air quality, cost savings, job creation, and improved resilience to help community leaders make informed decisions.

While this CCAP outlines more than 60 emissions reduction measures, there are six "Go Big Strategies" that form the core of this plan. These six strategies can provide significant economic impact and have the potential to seed pockets of growth within the MSA.

These six approaches include:

1. Expanding Nuclear Generation at Perry Nuclear Power Plant
2. Developing Offshore Wind on Lake Erie
3. Net Zero Steelmaking at Cleveland-Cliffs
4. Expanding Passenger Rail and Light-Rail Service
5. Developing a Regional Direct Air Capture (DAC) Facility to remove carbon from the atmosphere
6. Implementing a "Headwaters Forests Initiative" to reforest 10 square miles of the region's headwaters

Just as Mayor Stokes realized over 50 years ago, our environmental, economic, and social challenges are intertwined, this time through a climate crisis that presents an enormous threat to the people and systems within the Cleveland-Elyria MSA. This CCAP can provide a guide for the Cleveland-Elyria MSA to become "almost legendary" again, this time as a leader in the protection of human health and well-being through acting on climate change.

Introduction

1. Introduction

1.1. Climate Pollution Reduction Grant Overview

On April 28, 1970, Cleveland Mayor Carl Stokes told a U.S. Senate subcommittee that “We in Cleveland sit on the banks of a river and lake which become almost legendary, not only in the United States but abroad.”[3] Mayor Stokes stood at the vanguard of an effort to convert a burning river into a movement against the devastating impact of human pollution on the nation’s waterways, air quality, shared natural systems, and human health. Critically, Mayor Stokes did not see the region’s common environmental challenges as an isolated issue. Rather, he knew they were intricately connected with other pressing problems, including housing, jobs, and poverty, and he recognized that these regionwide social and environmental problems required regional solutions.[4]

More than 50 years later, the Cleveland-Elyria Metropolitan Statistical Area (MSA) faces another daunting environmental, economic, and social crisis. Climate change is here. According to the *Fifth National Climate Assessment* (NCA5), the evidence that the climate is changing is “incontrovertible". The report also concluded that “the science is unequivocal” that the addition of GHGs to the atmosphere by humans is driving these trends.[5] Every region of the country is already feeling the impacts of climate change. The U.S. has warmed 60% faster than the planet as a whole since 1970, there has been an increase in the frequency and severity of extreme weather events, and both drought and heavy precipitation have become more common.[6]

While the impacts of climate change are already occurring, the future is not predetermined. If leaders fail to act, the impacts will worsen, and climate change will pose a serious threat to the Cleveland-Elyria MSA (see Chapter 4). But, because humans have caused climate change, we also have the power to stop it. As the NCA5 makes clear, “how much more the world warms depends on the choices society makes today. The future is in human hands.”[7]

Congress has taken steps to reduce the threat of a changing climate. Section 60114 of the Inflation Reduction Act (IRA) created the Climate Pollution Reduction Grants (CPRG) Program and appropriated $5 billion to U.S. EPA to help states, territories, municipalities, tribes, and similar groups develop and implement plans to reduce climate pollution.

The program divided funding into three buckets:

- CPRG Planning Grants ($250 million) for eligible entities to develop emissions reduction plans with actionable measures;
- CPRG Implementation Grants ($4.6 billion) for the implementation of measures identified in emissions reduction plans;
- Administrative costs ($142.5 million).

According to U.S. EPA, the Agency identified three main objectives for the CPRG program:[8]

- Tackle climate pollution while also supporting the creation of good jobs and lowering energy costs for Americans;
- Accelerate work to address unequal exposure to environmental harms and to empower communities to address these disparities;
- Deliver cleaner air through reduced emissions of harmful air pollutants.

Addressing the challenge of climate change again requires us to recognize that our challenges are interconnected, and we must work collaboratively across sectors and jurisdictions. The Northeast Ohio Areawide Coordinating Agency (NOACA) and the City of Cleveland partnered in spring 2023 to develop a CPRG workplan and budget to help scale up established local climate action planning and pollution reduction efforts to the MSA level. Through this partnership, NOACA developed the first CPRG Program deliverable, the Priority Climate Action Plan (PCAP), in close partnership with the City of Cleveland and submitted it to U.S. EPA on February 28, 2024.[9] This PCAP, which outlines 10 community priorities for emissions reduction measures, laid the foundation for Cuyahoga County, the City of Painesville, and the City of Cleveland to secure a $129.4 million CPRG Program Implementation Grant that will fund the installation of 63 megawatts (MW) of solar energy and battery storage on landfills and brownfields throughout the MSA. NOACA will also lead the development of the final deliverable, the Status Report, in 2027.

1.2. CCAP Purpose and Scope

The City of Cleveland has partnered with NOACA, Cuyahoga County, and a group of researchers and experts from Case Western Reserve University (CWRU), Cleveland State University (CSU), and Kent State University (KSU) to develop this CCAP. This plan builds upon the existing climate planning work within the Cleveland-Elyria MSA. The CCAP expands upon the PCAP: the CCAP authors incorporate updated information on GHG emissions in the region; establish regional emissions reduction targets; identify a full suite of emissions reduction measures across all significant GHG emissions sources; assess the benefits of these actions to the MSA; and provide a workforce development assessment for the MSA.

The PCAP, in turn, built off the preliminary climate action planning work that NOACA initiated in 2021 through the support of the Cleveland Foundation and the George Gund Foundation. As part of this framework, NOACA utilized support from the Foundations to contract with ICLEI USA and initiate a Regional CAP. NOACA's Policy Committee supported a comprehensive approach for NOACA climate action planning: staff inventoried both mobile and stationary sources of GHG emissions and developed both mitigation (reduce emissions) and adaptation (build resilience to climate change) strategies. NOACA committed to emulate this model and completed both a published GHG emissions inventory (2022) and a draft Climate Risk and Vulnerability Assessment (CRVA) (2023) in partnership with ICLEI USA. NOACA had also initiated efforts to develop adaptation and mitigation strategies prior to US EPA's release of its Notice of Funding Opportunity (NOFO) and Guidance for the CPRG Program in spring 2023.

The CCAP also incorporates the extensive climate planning work that has already occurred in the Cleveland-Elyria MSA. A number of communities and key organizations have developed CAPs. The City of Oberlin was on the leading edge of this work (since 2007) and adopted its first CAP in 2011 (subsequent updates in both 2013 and 2019). Oberlin has established ambitious targets to reduce its GHG emissions by 75% through 2030 and to achieve negative emissions by 2050.

The City of Cleveland also has an extensive background in climate and sustainability planning. Cleveland established the Mayor's Office of Sustainability and Climate Justice (MOS) in 2005 and developed its first CAP in 2013. Cleveland has since updated its CAP in 2018 and 2025; became the first Ohio city to pledge 100% clean energy by 2050 through its 2021 *Clean and Equitable Energy Report*; achieved Leadership in Energy and Environmental Design (LEED) Silver City certification in 2021; and published its *Circular Cleveland Roadmap* in 2022. As part of its 2025 CAP update, Cleveland adopted ambitious, science-based targets (SBTs) to cut GHG emissions by 63.3% from 2018 levels in 2030 and reach net zero emissions by 2050. Several other entities in the Cleveland-Elyria MSA have also developed CAPs: Cuyahoga County (2019); the Greater Cleveland Regional Transit Authority (GCRTA) (2022); the City of Lakewood (2023); the City of Cleveland-Cuyahoga County Port Authority (2023); and the City of Cleveland Heights (2024).

In its guidance, U.S. EPA requires that CCAPs contain the following elements:[10]

- GHG emissions inventory (Chapter 2);
- GHG emissions projections (Chapter 6);
- GHG reduction targets (Chapter 3);
- Quantified GHG reduction measures (Chapter 7);
- A benefits analysis for the full geographic scope and population covered by the plan (Chapter 8);
- A low-income and disadvantaged communities (LIDAC) benefits analysis (optional as of April 22, 2025) (Chapter 9);[11]
- A review of authority to implement (Chapter 10);
- A plan to leverage other federal funding (Chapter 11); and,
- A workforce planning analysis (Chapter 12).

1.3. Decarbonization Framework

This CCAP also builds upon the *Cleveland Regional Decarbonization Pathways Report*, a 2023 analysis of potential pathways to net zero emissions in Northeast Ohio created through a partnership among the City of Cleveland, CWRU, Evolved Energy Research (EER), and the Sustainable Development Solutions Network (SDSN).[12] Several of the researchers involved in drafting that report formed the Cleveland Regional Decarbonization Framework (CRDF) team. This partnership of researchers from CWRU, CSU, and KSU developed the CCAP's technical analysis.

Decarbonization is the removal of climate pollution emissions, like CO_2 and CH_4, from the economy. Because the Cleveland-Elyria MSA currently depends on burning fossil fuels to generate electricity, operate cars, and warm buildings, it will require a long-term, concerted effort to use energy more efficiently and shift energy generation to renewable or zero-emissions sources (e.g., solar or nuclear). **Table 1** describes the principles of decarbonization. This CCAP illustrates a systems-level approach to tackling climate change. Decarbonization differs from climate adaptation, which describes actions that modify systems and infrastructure to adjust to a changing climate.

Table 1: Principles of Decarbonization

Decarbonization Principle	Description
Use Energy More Efficiently	Low Cost – Short-term return on investment (ROI) - Optimizes use - Saves Money - lowers the amount of renewable energy needed to meet demand.
Switch from burning fossil fuels to renewable or zero-emissions sources	Construction of new energy generation to replace fossil fuels. Includes switching from gasoline and diesel to batteries, Hydrogen and other clean fuels for cars, trucks, planes and ships.
Electrification	Replace gas-burning appliances, industrial equipment and furnaces with electric equivalents.
Capture and store carbon	Remove GHGs from the atmosphere, or capture them at point of emissions, using man-made and nature-based solutions.
Effective planning must be coordinated and integrated	Community planning is coordinated with neighboring communities, counties, political subdivisions and key stakeholders.

Many natural and human-made processes use carbon from the atmosphere. Trees, for example, absorb CO_2 from the atmosphere and use that carbon to build their trunk and branches. While eliminating all GHG emissions by 2050 remains a goal, the most important target is for the Cleveland-Elyria MSA to reach net zero (i.e., natural and human-made uptake of carbon equals carbon emissions). However, natural systems capture carbon slowly, and current man-made systems are very expensive. While necessary, carbon capture is only a small part of the solution.

1.4. MSA Context

This CCAP covers the Cleveland-Elyria MSA, as defined in the 2010 U.S. Census. This metro area, which incorporates Cuyahoga, Geauga, Lake, Lorain, and Medina Counties, aligns with the NOACA MPO planning area.[13] While a number of other geographic areas are of interest from a regional climate planning perspective (e.g. Lake Erie watershed, the Northeast Ohio air quality planning area, the 12-county Northeast Ohio Sustainable Communities Consortium (NEOSCC) region), the CCAP focuses exclusively on the five-county MSA. Nevertheless, elements of this plan, such as emissions reduction measures, approaches to community engagement, and the GHG emissions inventory, are applicable to communities outside of the MSA.

The Cleveland-Elyria MSA covers a total area of 3,979 square miles, of which roughly half (1,999 square miles) is land area.[14] The five counties in the MSA include 61 cities, 45 villages, and 58 townships that are home to just over 2.08 million people.[15] The MSA's population has decreased by roughly 10% since the 1970s, and the region has demonstrated a continued pattern of outward migration and suburbanization. The MSA's largest county (Cuyahoga) and city (Cleveland) have seen their populations decline by approximately 13% and 28% since 1990, respectively.[16] Much of this shift occurred prior to

2010, and the population of both Cuyahoga County and the City of Cleveland have stabilized since that point. Population growth within the MSA is largely concentrated outside of Cuyahoga County. Since 1990, the populations of Geauga (18%), Lake (7%), Lorain (17%), and Medina (50%) Counties all increased. Nevertheless, the growth in these counties has not been enough to offset the population declines in Cuyahoga County's over the past several decades.[17]

The Cleveland-Elyria MSA is highly diverse in terms of demographics, economic characteristics, and settlement patterns, as discussed in the following sections.

1.4.1. Demographics

Nearly seven in ten (69.6%) of the MSA's residents identified as white during 2023, with one in five (19.3%) identifying as Black or African American. Approximately 3% of the MSA's residents identified as two or more races, while roughly 2% identified each as Asian (2.4%) or some other race (1.9%).[18] Demographics differ within the region; non-white population ranges from a low of 6% in Geauga County to a high of 41% in Cuyahoga County. Approximately 7% of the Cleveland-Elyria MSA identifies as Hispanic or Latino, from a low of 2% in Geauga County to a high of 11% in Lorain County.[19] The median age of Cleveland-Elyria MSA residents is approximately 41.6 years; this is 2.4 years older than the median age of the United States. Nearly one in five residents (19.4%) is age 65 or over, which is also higher than the overall nation (16.8%).[20] International migration has been the primary source of population replacement for many communities. From 2014-2018 to 2019-2023, more than 5,600 international migrants moved into the Cleveland-Elyria MSA.[21] Immigration has been even more important to the urban core, as international migrants offset population decreases from other demographic groups Cuyahoga County and the City of Cleveland in recent years.

1.4.2. Economic Characteristics

In recent decades, the number of jobs in the Cleveland-Elyria MSA increased by just 26,000. This relatively steady trend masks significant variation, as the number of jobs increased by 10% during the 1990s, declined by 13% during the 2000s, and increased again from 2010 to 2023.[22] While the region's economy has recovered since the Great Recession, the Cleveland-Elyria MSA still has fewer jobs in 2023 than it did in 2000. Much like population, employment has moved away from the urban core. While the number of jobs has increased, the share of jobs located within Cuyahoga County has declined from 76% in 1990 to 70% by 2023.[23] Downtown Cleveland and Cleveland's University Circle remain the MSA's two largest job hubs, but there has been a significant concentration of jobs into hubs outside of the core, including the Aerozone (Cuyahoga), Avon (Lorain), Chagrin-Highlands (Cuyahoga), Elyria (Lorain), Independence (Cuyahoga), Mentor (Lake), and Strongsville (Cuyahoga).[24]

Across the MSA, employment has shifted from the basic/industry sector to the service sector. From 1990 to 2023, the number of basic sector jobs (e.g. construction, manufacturing, transportation and warehousing, utilities) declined by nearly 90,000. These job losses overwhelmingly occurred during the 2000s, when the number declined by 115,000.[25] In contrast, service sector employment has grown by 23% since 1990, more than enough to offset all job losses in the basic sector. Much of this job growth has occurred in healthcare and education, which accounted for nearly one in five jobs (18%) in the MSA during 2024. Healthcare accounts for 30% more employment in the Cleveland-Elyria MSA than in the nation, as a whole, and the region's largest single employers are healthcare institutions.[26] Nevertheless, the region retains a robust manufacturing base, and the industrial sector accounts for a substantial share of both economic output and climate pollution emissions, as discussed in Chapter 2.

1.4.3. Settlement Patterns

Settlement patterns in the Cleveland-Elyria MSA run the gamut from rural to dense urban cores. As part of *Vibrant NEO 2040*, NEOSCC staff developed a six-part typology of communities within Northeast Ohio, outlined in **Table 2**.[27] The CCAP applies this typology to identify which emissions reduction measures are most applicable to different portions of the Cleveland-Elyria MSA.

Table 2: Typology of Communities in Cleveland-Elyria MSA

Typology	Description	Example Communities
Legacy Cities	Cities developed before 1910 that have historically played a significant role in manufacturing and industry and serve as the traditional cultural, social, educational, and economic centers of the region	Cleveland, Elyria, Lorain
First Ring Suburbs	Communities adjacent to Legacy Cities that developed from 1910-1950, encouraged by desire to leave sometimes undesirable living conditions. They may be connected by early public transit systems, and they developed minor urban centers like commercial main streets and civic centers	Shaker Heights, Sheffield, Wickliffe
Second Ring Suburbs	Communities one step out from First Ring Suburbs established from 1950-1970, which reflect the growing impact and convenience of automobiles and a desire to migrate away from center cities. They may or may not have community centers, defined commercial nodes, and concentrated employment hubs	Amherst, Kirtland, Wadsworth
Outer Ring Suburbs	Communities located within a 30-minute drive of Legacy Cities that developed largely due to the post-1970s freeway network. Growth was based on new large-lot housing stock and the redefinition of commercial and employment centers	Auburn, Brunswick Hills, Strongsville
Established Cities or Towns	Communities that developed independent of the Legacy Cities. These often serve as the local economic, governmental, or institutional centers and reflect a variety of residential, commercial, and cultural traits	Chardon, Oberlin, Painesville
Rural Townships	Communities located outside of urban areas that are primarily rural and agricultural. They may have small town centers with municipal and commercial facilities, but these public amenities are not typically connected to one another	Burton Township, Grafton Township, Madison Township

Given the broad diversity of settlement patterns and population densities, relevant approaches to climate action will vary by location. Efforts to decarbonize steel production are essential for the City of Cleveland, where the Cleveland Works integrated steel facility accounts for one-third of climate pollution emissions, but they are not applicable to rural townships, where agricultural emissions are of greater concern. Other actions, such as efforts to invest in clean energy generation, electrify passenger vehicles, and invest in nature-based solutions, will be broadly applicable across the MSA.

1.5 Approach to CCAP Development

The development of this CCAP began immediately after PCAP approval on March 7, 2024. The primary CCAP partners – the City of Cleveland, NOACA, and Cuyahoga County – held a series of coordination workshops during March and April 2024 to discuss the CCAP development process and the roles that each partner would play.

1.5.1. City of Cleveland

As the CCAP lead, the City of Cleveland managed the development of this plan. MOS staff developed the project management plan that guided CCAP completion; created the scope of work that defined the responsibilities of the CRDF team; coordinated regularly with the CCAP partners and CRDF team; managed the execution of CCAP elements; and coordinated the plan draft. The City oversaw the work of the CRDF team and ensured that it delivered all required CCAP elements outlined in the scope of work and in EPA's CPRG guidance. Through the leadership of the Mayor's Office of Sustainability and Climate Justice (MOS), the City of Cleveland directly managed the completion of required CCAP elements.

The City completed the *2022 Regional Greenhouse Gas Emissions Inventory: Cleveland-Elyria MSA* during summer-fall 2024 (see Chapter 2). MOS staff then used the updated emissions data to develop proposed emissions reduction targets (see Chapter 3). Cleveland coordinated with NOACA to bring these proposed targets to the NOACA Board of Directors for approval in December 2024. MOS also conducted extensive public outreach and engagement efforts within the City of Cleveland during 2023-2024, with a specific focus on LIDAC communities, and engaged regularly with CCAP partners and stakeholders throughout the Cleveland-Elyria MSA. In addition, MOS staff worked with several partner organizations – including Cuyahoga County, the Cleveland Foundation, the Deaconess Foundation, the Fund for Our Economic Future, the George Gund Foundation, the Greater Cleveland Partnership, and Greater Cleveland Works – to complete a Climate Workforce Assessment and Development effort that informed the Workforce Planning Analysis (see Chapter 12).

1.5.2. NOACA

As the CPRG lead organization, NOACA plays the central role in CPRG planning grant management and guides CCAP completion. NOACA staff coordinated meetings among CCAP partners and between CCAP partners and U.S. EPA. NOACA staff also worked extensively with its Subaward recipients to document work progress and properly invoice US EPA to ensure smooth drawdowns of funds. NOACA worked closely with the City of Cleveland to complete the *2022 Regional Greenhouse Gas Emissions Inventory: Cleveland-Elyria MSA* and to develop regional emissions reduction targets. Furthermore, NOACA led public engagement efforts throughout 2023-2025 to ensure that this CCAP reflects and incorporates feedback from residents and stakeholders across the MSA, particularly those living in LIDACs. NOACA led the effort to ensure broad engagement with and support for the CCAP from across the MSA.

1.5.3. Cuyahoga County

As a subawardee of the City of Cleveland, Cuyahoga County oversaw efforts to develop CCAP elements within areas of the County outside the City of Cleveland. The Cuyahoga County Department of Sustainability worked closely with the City of Cleveland and NOACA to deliver multiple required CCAP elements, including creating an updated County Greenhouse Gas Emission Inventory, which directly supported the completion of the 2022 Regional Greenhouse Gas Emissions Inventory: Cleveland-Elyria MSA, and worked with the City of Cleveland and other partners to deliver the Climate Workforce Assessment and Development report. Department of Sustainability staff engaged with municipalities throughout Cuyahoga County to understand their climate-related priorities and provide them with tools and resources to engage with their residents, including those in LIDAC areas (page 23).

1.5.4. Cleveland Regional Decarbonization Framework (CRDF) Team

In June 2024, the City of Cleveland contracted with CWRU to form a CRDF team that would execute several required CCAP elements. CWRU partnered with researchers and staff from CSU and KSU to complete this work. Based on the scope of work, the CRDF team formed sectoral/focus area working groups led by relevant subject matter experts from the three universities. These working groups included the Building Sector, Cost-Benefits Analysis, Energy Sector, Industrial Sector, Jobs Analysis, Land Use Sector, Stakeholder Engagement, and Transportation Sector.

Through regular coordination with one another and the CCAP partners, these CRDF working groups managed the completion of several required CCAP elements. They built upon the work that NOACA and ICLEI USA completed for the PCAP to develop an updated Business As Usual (BAU) scenario (see Chapter 6). They coordinated with the City of Cleveland, NOACA, and Cuyahoga County to gather feedback from public and stakeholder engagement efforts and used this feedback to inform the identification and assessment of GHG emissions reduction measures. Based upon this feedback, they identified and analyzed the GHG emissions reduction measures discussed in Chapter 7 to ensure these measures aligned with the PCAP and other CAPs from across the MSA (e.g., 2025 CAP updates from City of Cleveland and Cuyahoga County). The CRDF team also completed the benefits analysis for the MSA and LIDAC areas for each emissions reduction measure and for the CCAP (see Chapters 8 and 9, respectively). Lastly, the CRDF team built upon the Climate Workforce Assessment and Development report to complete the Workforce Planning Analysis for this CCAP (see Chapter 12).

1.6. Public and Stakeholder Engagement

In the Next Steps section of the PCAP, staff promised that NOACA and the City of Cleveland would expand on their engagement efforts in LIDACs, with focused guidance from LIDAC representatives who know best how to reach the most critical audiences in their jurisdictions. This expanded engagement is essential to ultimate buy-in from LIDAC stakeholders and provides a sense of ownership and optimism about their future in a world reshaped by climate change. Given the breadth of the Cleveland-Elyria MSA and the parallel work by the City of Cleveland and Cuyahoga County to update their own CAPs, the collaborating partners decided to parse the region into three sections for the purposes of engagement. The City of Cleveland and Cuyahoga County would each engage constituents in their respective jurisdictions (the County would focus on communities outside Cleveland) and NOACA would focus on LIDACs within the four counties outside Cuyahoga (Geauga, Lake, Lorain, and Medina). The following sections highlight each partner's effort to engage LIDAC stakeholders on climate action.

1.6.1. City of Cleveland

The City of Cleveland focused its engagement efforts during a 12-month period (October 2023 – October 2024) to serve dual purposes: 1) produce its 3rd CAP update for city constituents and 2) incorporate meaningful engagement into CCAP content for the five-county MSA. City of Cleveland staff implemented two phases of engagement. The first focused on an update to the City's Climate Risk and Vulnerability Assessment (CRVA) (2023) and the second focused on community climate action engagement to fill participation gaps from the CRVA phase and weave city and regional climate priorities and concerns together. Overall, the City implemented two surveys (767 respondents who either lived or worked in Cleveland); 10 engagement sessions (268 attendees); and four (4) educational workshops (114 attendees). This amounted to more than 1,000 participants, the majority from LIDACs.

CRVA Engagement (2023): MOS staff kicked off the CAP community engagement process during fall 2023 as part of the City's CRVA update. The two primary components of this engagement were the survey and four public engagement sessions for residents. The survey netted a majority (52%) of responses from (LIDACs). However, MOS staff recognized that survey respondent demographics did not necessarily mirror those of Cleveland residents (i.e., respondents were whiter, more educated). Therefore, MOS staff targeted the four public engagement sessions for residents in neighborhoods that had lower survey response rates or were more vulnerable to key hazards: Central-Fairfax, Clark-Fulton, Downtown, and Union-Miles. MOS staff tapped local community organizations familiar with these areas and skilled in outreach to help promote each session to members of the community. A Spanish interpreter was available at the engagement session located in Clark-Fulton. As with the survey, most (56%) session participants were residents of LIDACs.

Cleveland Community Climate Action Engagement (2024): MOS staff kicked off the second phase of its engagement effort with another survey during the summer of 2024: The Cleveland Community Climate Action Survey. MOS staff presented both English and Spanish versions of the survey, both online and on paper. The survey included 17 questions to help elicit information about respondents, measure community support for potential CCAP goals and actions; and rank factors the City of Cleveland and its partners might use to evaluate and prioritize climate actions. Upon review of the survey responses, MOS staff highlighted some common themes:

- More green space access;
- More equitable access to local food and agriculture to address food deserts and insecurity;
- Promote economic and job development opportunities within climate initiatives;
- Increase climate education and literacy;
- Improve access to alternate transportation methods; and
- Focus on litter cleanup and better waste management practices

Parallel to the CRVA engagement phase, MOS staff followed the Community Climate Action Engagement Survey with six (6) LIDAC roundtables, especially neighborhoods that had lower rates of survey responses, were more likely to benefit from climate actions, and did not host CRVA engagement sessions the prior year.

As they did with the CRVA public engagement sessions, MOS staff tapped community-based organizations (CBOs) to help plan and promote each roundtable. These partners included the Ohio Environmental Council (OEC), H.E.A.L Buckeye, Young Latino Network, Organic Connects, Village Family Farms, and See You at the Top (SYATT). MOS staff structured each engagement session to include the following:

- Facilitated discussions on the impacts of climate change in the given neighborhood;
- Review of participants' aspirations for their neighborhoods;
- Participants selected one of the CAP focus areas and discussed priority actions, potential barriers to action, and likely blind spots the City may experience in climate planning;
- Brief exit survey that helped identify attendees' top priorities for climate action in Cleveland. Community members were most concerned about:
    - Clean water
    - Clean air
    - More trees
    - Green space
    - Financial assistance for home improvements

Finally, MOS staff partnered with CBOs to organize and execute Educational Workshops: Diving into Climate Action, a series of four engagement workshops with each workshop centered on different topics and communities:

- FreshFest (Ohio Environmental Council);
- Nature-Based Solutions Walking Tour of Slavic Village (Slavic Village Development, Westcreek Reservation, NEORSD);
- Food, Mobility, and Climate Justice Forum (My Grow Connect, Cuyahoga County Food Policy Coalition, Cleveland Planning Commission); and
- Youth Climate Action Educational Forum (Cleveland Public Library, Cleveland Metropolitan School District)

1.6.2. Cuyahoga County

The Cuyahoga County Department of Sustainability conducted stakeholder engagement activities to inform the Cuyahoga County Climate Action Plan update and to create opportunities for dialogue and shared learning focused on climate change for the regional CCAP.

Aspen Institute and Cuyahoga County Climate Roundtable: Cuyahoga County hosted a Climate Roundtable in July 2024 to highlight climate realities and solutions in Northeast Ohio. The discussion focused on identifying partnerships for climate action in Cuyahoga County in partnership with the Aspen Institute. The two organizations selected a group of participants, who discussed the resources and knowledge available to local governments to adapt to the effects of a changing climate and invest in their vision. The hosts selected participants to represent a range of sectors and perspectives. Hosts built the agenda of the roundtable around existing priorities in the local climate action context. The dialogue added value and was designed to inform the County's CAP update.

Staff used the roundtable as a learning opportunity around effective engagement to generate and sustain climate action in Cuyahoga County. A pre- and post-event survey helped staff analyze open dialogue; the survey focused on connections and collaborations among participants. Responses showed the event created new connections among 76% of attendees surveyed and strengthened connections across the nonprofit, education, government, and business sectors. The results demonstrate that this style of dialogue is critical to enable a forward direction for climate action. County staff will incorporate key lessons learned from the roundtable into its CAP and the regional CCAP.

Did any fellow participants meaningfully shape or change your perspectives or approaches to the topics discussed during the roundtable?

33%
They took the time to explain themselves and help me understand the rationale for their perspectives and approaches.

What was it about your interactions that helped shift your perspectives or approach?

67%
I better understand the core commitments, concerns, and realities that shape others' perspectives and approaches.

Community Collaboration Survey: In 2024, Cuyahoga County asked all jurisdictions to complete a Regional Collaboration Survey which included questions specific to climate action and sustainability. 42 of 57 communities (74%) completed the survey and ranked the following climate action areas as their highest priorities:

- Tree Planting and Maintenance;

- Energy Efficiency in Municipal Operations; and
- Sustainable Municipal Procurement

Jurisdictions also indicated they were open to collaboration with the County on these topics:

- Uptake on IRA tax credits and rebates for residents and businesses;
- Renewable energy and energy efficiency for residents and businesses;
- Single-use plastics reduction;
- Electric vehicle transition; and
- Greenhouse gas inventory

Municipal Climate Collaboration: Based on the results of the Community Collaboration Survey and building off the Climate Roundtable Discussion, the Department of Sustainability will provide technical assistance to jurisdictions within Cuyahoga County.

All jurisdictions received GHG inventories with scope 1 and 2 emissions within their city boundaries. County staff provided data, key insights, and an executive summary, along with some priority climate action areas based on jurisdictions' unique climate footprint.

Additionally, the Department of Sustainability provides climate action technical assistance around climate action measures supported through this CPRG planning grant to select jurisdictions. The purpose is to pilot a program where a signature climate action of the County is to support communities within the County that want to take climate action.

The next phase is to share key lessons learned and use this foundation to launch periodic sessions where communities can connect to share information and best practices. Collaboration with the Mayors and Managers Association of Cuyahoga County and the First Suburbs Consortium is a key engagement strategy of the Department of Sustainability.

Community Engagement: Community engagement is an important part of the Department of Sustainability Strategy, with outreach on sustainability and climate-related topics being a priority throughout the year. The Department of Sustainability hosts monthly webinars and participates in several tabling, speaking, and volunteer events throughout the year. The County values those conversations with residents, businesses, and other stakeholders.

In 2024, Cuyahoga County participated in 26 community events during which staff conducted engagement and educational activities with the public related to sustainability and climate change. Eleven of these events in Equity Zones, which are designated areas of historic disinvestment.[28] The County Sustainability Department tracks the number of people actively engaged with its efforts (2,799 people engaged in 2024).

1.6.3. NOACA

As part of its CPRG work, NOACA retained Joel Ratner Community Partnership (JRCP) to conduct outreach focused on LIDACs in the region during fall/winter 2024-2025. This circumscribed effort followed a robust and comprehensive outreach effort previously completed by JRCP for NOACA.

This LIDAC outreach also focused on a smaller geographic footprint within the five-county NOACA region. Outside Cuyahoga County, LIDAC Census tracts exist in the cities of Elyria and Lorain (Lorain County); the City of Painesville (Lake County); and several, small unincorporated areas on the eastern edge of Geauga County. There are technically no LIDAC Census tracts in Medina County.

In the previous large-scale engagement process, JRCP conducted 30 community engagement sessions in the five-county region. In total, approximately 700 people participated in those meetings. Because this earlier process (summer/fall 2023) was so comprehensive, JRCP and NOACA focused more intently on representative residents in LIDACs in this process. JRCP partnered closely with organizations that work with or serve LIDAC populations. In this way JRCP leveraged the trust and access of these partners.

Partners included:

- Lorain City Schools;
- The YWCA in Elyria;
- HOLA Ohio, serving immigrant and refugee families;
- Gathering Hope House, serving the mentally ill and dual and multiple diagnosis; and
- Soprema Senior Center

JRCP identified these groups through a rigorous search for partners and session hosts. JRCP conducted an extensive process, approaching multiple groups providing services in each LIDAC, including nonprofits and governmental agencies with access to the targeted population.

In total, 142 people participated in community engagement sessions (based on sign-in sheets). Of these, 128 returned a questionnaire/response sheet. This represents a 90% response rate. It is not clear why some individuals did not return a form, but every effort was made to encourage them to do so. At the two sessions hosted by HOLA Ohio, virtually all the responses were in Spanish and were translated by HOLA Ohio staff.

Of those that signed in and provided an address, most were from the cities of Painesville, Elyria and Lorain, all cities which have significant numbers of LIDAC Census tracts. Excluding the Medina County session (without LIDAC Census tracts), a total of 126 participants provided a physical address when they signed the sheet. Of these who signed in with an address, 113 listed addresses in these three cities, representing almost 90% of participants.

Each session had an identical format. As participants entered the room, they were encouraged to sign the available attendance sheet. Each seat in the room held a one-page summary of the Regional Climate Action Priorities which were developed as part of the Cleveland-Elyria MSA PCAP. JRCP began the session with a PowerPoint presentation (developed in partnership with NOACA staff). Once JRCP staff concluded the presentation, they distributed questionnaires and facilitated discussions.

The engagement sessions showed deep concern about air quality and climate change impacts, generally. The three hazards that most concerned participants were:

- Air Quality Concerns;
- Severe Thunderstorms; and
- Water Pollution

In this LIDAC-focused engagement effort, there was strong support for the Regional Climate Action Priorities. The three highest priorities were:

- Clean Electricity;
- Building Efficiency and Electrification; and
- Vehicle Miles Traveled Reduction

As a follow-up to the question about priorities, JRCP staff asked participants whether there are other important actions to address climate change. In total, 81 participants responded to this question. Responses varied widely, including

- One person reflecting the views of many, stated that "they are all important and it is up to our government to do the right thing and make steps in the right direction;"
- Others were most concerned about power generation and were interested in solar and other sustainable sources of power. Many cited a need for "clean electricity;"
- Many suggested the need for "affordable solar panels;"
- Another participant indicated a desire for more "use of clean energy;"
- In Painesville there was near universal and strong support for closing a local coal burning power plant;
- Many discussed electric cars or other improvements to transportation which would reduce greenhouse gas emissions;
- "The transportation is a big deal;"
- One person stated "Clean up the Lake and the River;"
- A number of participants mentioned "clean water." Others discussed breathing problems and the need for clean air;
- Some participants responded to this question by supporting tree planting; and
- Several participants wrote: "Plant more trees" or simply "trees."

While generally there was approval around pursuing the climate action priorities, there is some concern about the financial costs associated. In particular low-income participants worry about how practical and affordable these solutions will be for them. Many of those who participated indicated gratitude for being consulted. JRCP made a strong effort to authentically engage those from LIDACs with the assistance of nonprofit and governmental partners who serve this population. Those who participated reflected a broad range by age, race, and ethnicity.

2022 Regional Greenhouse Gas Emissions Inventory: Cleveland-Elyria MSA

2. Cleveland-Elyria MSA Greenhouse Gas (GHG) Inventory

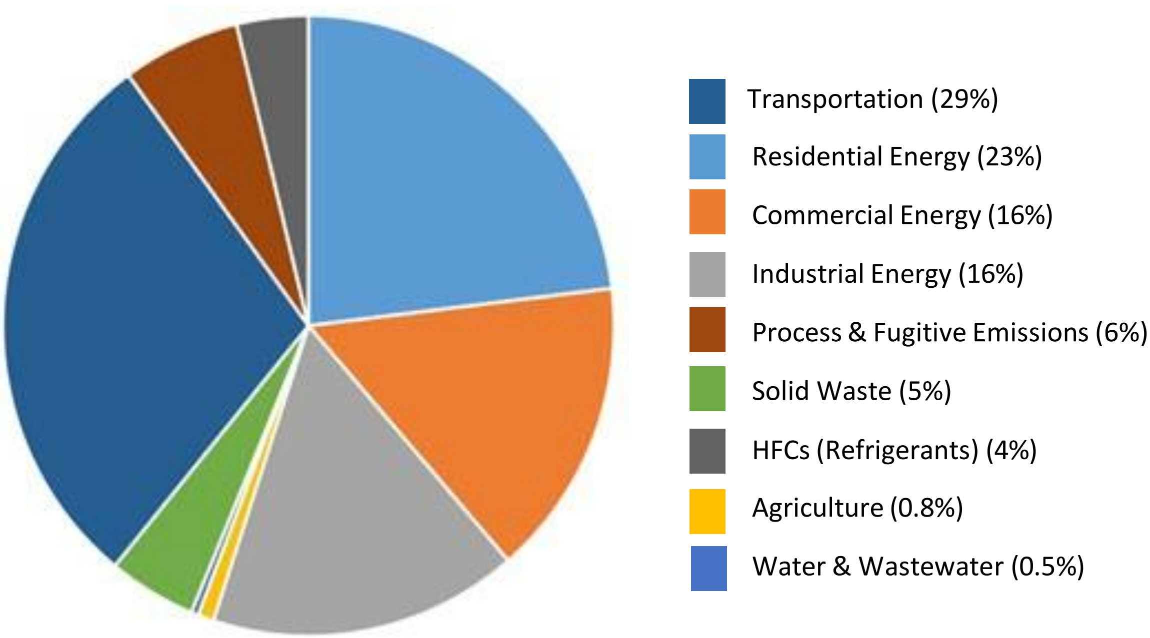
2.1. Inventory Overview

This section provides estimates of GHGs from activities in Northeast Ohio – including Cuyahoga, Geauga, Lake, Lorain, and Medina Counties – during 2022. It also includes a comparison of emissions between the 2022 and 2018 baseline years. This chapter builds upon and enhances the 2018 GHG inventory completed for the PCAP and forms the foundation upon which the entire CCAP rests.

Figure 1, below, shows communitywide emissions by sector within the Cleveland-Elyria MSA during 2022. The largest contributor is Transportation with 29% of total emissions. The next largest contributors are Residential Energy (23%), Industrial Energy (16%), and Commercial Energy (16%). Process and Fugitive Emissions, Solid Waste, Hydrofluorocarbons (HFCs), Agriculture, and Water and Wastewater were responsible for the remaining emissions (less than 16%). Forests and trees sequester nearly 4% of emissions throughout the MSA.

GHG emissions during 2022 were 14.2% lower than in the 2018 baseline report. This reduction was more than twice the reduction (6.1%) that occurred nationally across that span.[29] Emissions fell for each of the five counties in the MSA and decreased for nearly all sectors. The only sector in which emissions increased was HFCs (Refrigerants).

Figure 1: 2022 Total Regional GHG Emissions by Sector



2.2. Inventory Methodology

The first step toward tangible GHG emission reductions requires identifying baseline emissions levels and sources and activities that generate emissions in the community/region. This section presents emissions from across the MSA. The government operations inventory is mostly a subset of the community inventory (see **Figure 2**). For example, data on commercial energy use by the community includes energy consumed by municipal buildings, and community VMT estimates include miles driven by municipal fleet vehicles.

Figure 2: Relationship of Regional and Government Operations Emissions Inventories

As local governments continue to act on climate, the need for a standardized approach to quantify GHG emissions has proven essential. This inventory uses the approach and methods provided by the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions (Community Protocol), discussed below.

This inventory includes emissions of the four most common GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). Other gases, such as perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) constitute very small percentages of emissions nationally (e.g. less than 1%). As such, they are not a focus of the emissions reduction measures outlined in this CCAP and are not included in this inventory.

Throughout this report, emissions are expressed as metric tons of carbon dioxide equivalent ($MTCO_2e$), calculated using the Global Warming Potential (GWP) values for methane and nitrous oxide from the Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Report*. **Table 3**, below, details the GWPs for different GHGs.

Table 3: Global Warming Potential Values

Greenhouse Gas	Global Warming Potential
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265

2.3. Regional Emissions Protocol

ICLEI released Version 1.2 of the U.S. Community Protocol for Accounting and Reporting GHG Emissions (Protocol) in 2019, and represents a national standard in guidance to help U.S. local governments develop effective community GHG emissions inventories.[30] The Protocol establishes reporting requirements for all community GHG emissions inventories, provides detailed accounting guidance for quantifying GHG emissions associated with a range of emission sources and community activities, and provides a number of optional reporting frameworks to help local governments customize their community GHG emissions inventory reports based on their local goals and capacities.

The regional inventory in this report includes emissions from the five Basic Emissions Generating Activities required by the Protocol. These activities are:

- Use of electricity by the region
- Use of fuel in residential and commercial stationary combustion equipment
- On-road passenger and freight motor vehicle travel
- Use of energy in potable water and wastewater treatment and distribution
- Generation of solid waste by the region

The regional inventory also includes the following activities to make it a Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Basic-compliant inventory:

- Wastewater treatment processes
- Rail, marine, and off-road transportation
- Forest and trees
- Industrial processes
- Scope 3 air travel

The inventory also includes HFCs (refrigerants) and emissions from the agricultural sector in order to comply with CPRG program guidance and feedback from CPRG outreach and engagement efforts during 2023.

2.4. Data Collection Methodology and Data Source Details

The City of Cleveland collected from a variety of entities in the region, including electric, gas, water and wastewater utilities. Methodology and data source details are detailed below in **Tables 4, 5,** and **6**.[31]

Table 4: Energy Data Sources with Estimation Applied

Activity	Data Source	Data Gaps/Assumptions
Region-wide		
Residential, Commercial, and Industrial Electricity	Firelands Electric Cooperative	Interpolated electricity usage for Lorain County by dividing total consumption for residential and commercial users during 2022, as reported to the United States Energy Information Administration (U.S. EIA), by the total number of residential customers, reported by the utility
	Lorain Medina Rural Electricity Cooperative	Interpolated electricity usage for Lorain and Medina Counties by dividing the total consumption for residential, commercial, and industrial users during 2022, as reported to the U.S. EIA, by the share of the total population of the utility's five-county territory located in Lorain and Medina Counties
Residential, Commercial, and Industrial Natural Gas	Columbia Gas of Ohio	Includes agricultural data
	Knox Energy Cooperative	Interpolated natural gas usage for each county by dividing the total consumption for residential, commercial, and industrial users during 2022, as reported to the U.S. EIA, by the share of the total population of the utility's 33-county territory located in Cuyahoga, Geauga, Lake, Lorain, and Medina Counties
	Northeast Ohio Natural Gas	Interpolated natural gas usage for Geauga and Lake Counties by dividing the total consumption for residential, commercial, and industrial users during 2022, as reported to the U.S. EIA, by the share of the total population of the utility's 15-county territory located in Geauga and Lake Counties
	Northern Industrial Energy Development	Interpolated natural gas usage for Medina County by dividing the total consumption for industrial users during 2022, as reported to the U.S. EIA, by the share of the total population of the utility's three-county territory located in Medina County

Table 5: Emissions Factors for Electricity Consumption

Utility / Year	CO_2 (lbs per MWh)	CH_4 (lbs per GWh)	N_2O (lbs per GWh)	Data Gaps/Assumptions
City of Amherst / 2022	1,042	87	12	Provided by American Municipal Power (AMP)
City of Oberlin / 2022	172	87	12	Provided by AMP
City of Wadsworth / 2022	774.41	43.87	6	Provided by AMP
Cleveland Public Power (CPP) / 2022	779.85	87	12	Calculated based on electricity data by source provided by CPP
FirstEnergy / 2022	810.84	87	12	Provided by FirstEnergy
Village of Grafton / 2021	825	87	12	Provided by AMP
Village of Seville / 2022	780.59	55.19	7.61	Provided by AMP

Table 6: Wastewater Data Sources with Estimation Applied

Activity	Data Source	Data Gaps/Assumptions
Region-wide		
N_2O from Effluent Discharge	Cuyahoga County (Bedford, Bedford Heights, Chagrin Falls, North Royalton, Strongsville)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N_2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
	Geauga County (Burton, Chardon, Geauga County Department of Water Resources)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N_2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county

Activity	Data Source	Data Gaps/Assumptions
N_2O from Effluent Discharge	Lorain County (Amherst, Avon Lake, Grafton, LaGrange, Lorain County Rural Wastewater District (LORCO), Oberlin, Wellington)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N_2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
	Medina County (Lodi, Seville, Spencer, Westfield Center)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N_2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
Process N_2O Emissions	Cuyahoga County (Bedford, Bedford Heights, Chagrin Falls, North Royalton, Strongsville)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
	Geauga County (Burton, Chardon, Geauga County Department of Water Resources)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
	Lorain County (Amherst, Avon Lake, Grafton, LaGrange, Lorain County Rural Wastewater District, Oberlin, Wellington)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county
	Medina County (Lodi, Seville, Spencer, Westfield Center)	Estimated emissions for small utilities for which staff did not receive data. Estimates based on the tons of N2O per million gallons per day (MGD) of wastewater treated, based on reported data for smaller utilities (less than five (5) MGD) located in the county

2.5. Sources and Activities

Communities contribute to greenhouse gas emissions in many ways. As **Table 7** explains, there are two main categorizations of emissions in a community inventory: 1) GHG emissions that are produced by "sources" located within the community boundary, and 2) GHG emissions produced as a consequence of community "activities."

Table 7: Source vs. Activity for Greenhouse Gas Emissions (GHG)

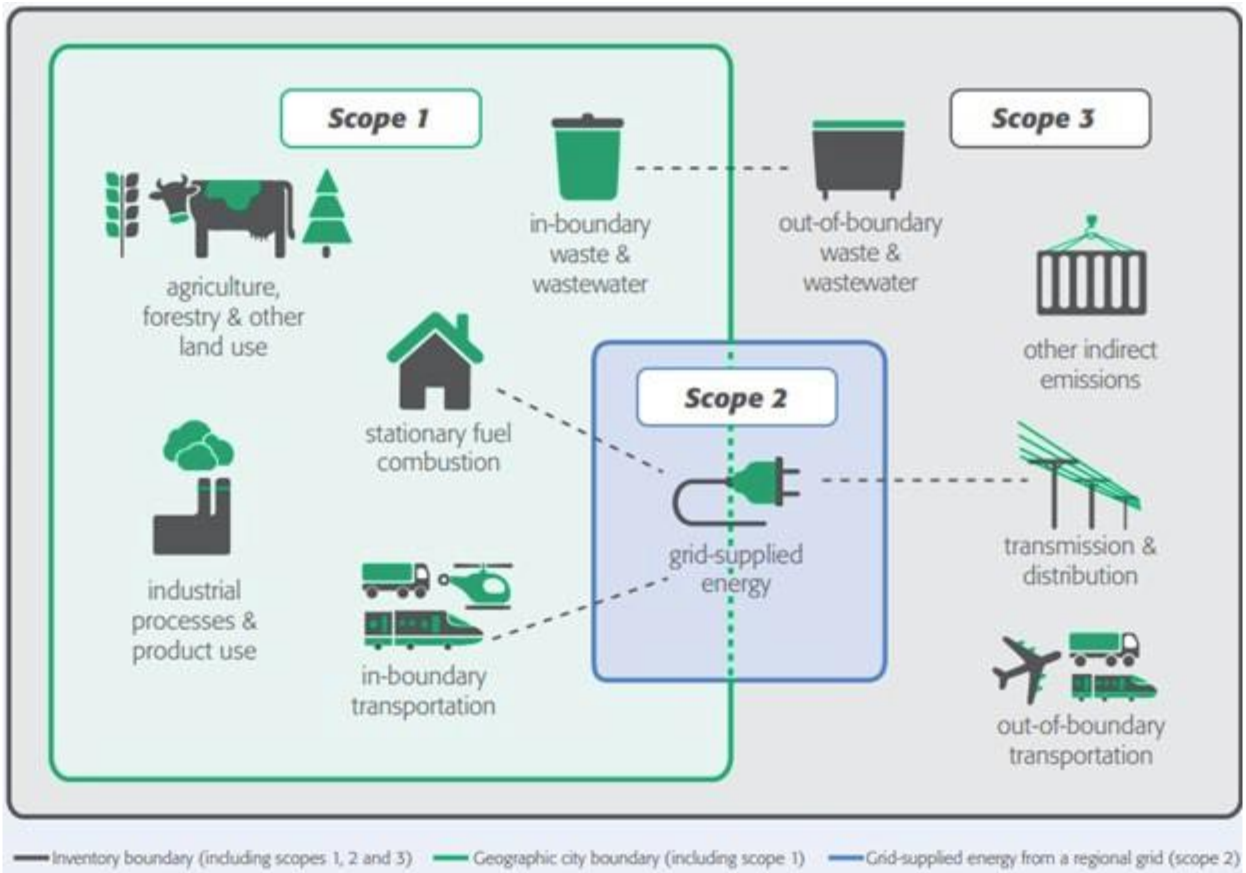
Source	Activity
Any physical process within the jurisdictional boundary that releases GHG emissions into the atmosphere	The use of energy, materials, and/or services by community members that result in GHG emissions, even if those emissions occur outside the jurisdictional boundary

Local governments can better understand and communicate their community's greenhouse gas (GHG) profile by reporting emissions in two complementary ways: **by source** and **by activity**.

- A **source-based inventory** measures all emissions that physically occur within the community's boundaries, providing an estimate of total GHGs released locally.
- An **activity-based inventory**, on the other hand, tracks emissions resulting from community activities—such as energy consumption or material use—regardless of where the emissions actually occur. This approach offers insight into the community's overall efficiency and impact, including emissions generated beyond its borders.

The GPC, in turn, divides community GHG emissions into Scopes 1, 2, and 3, rather than sources and activities. **Figure 3** outlines these scopes and how they align emissions sources and activities.

Figure 3: Emissions Sources and Activities by GPC Scope



The City of Cleveland and NOACA have ensured that this Cleveland-Elyria MSA GHG Inventory aligns with CPRG guidance from U.S. EPA. **Table 8** matches the different sources of emissions and emission generating activities within the Cleveland-Elyria MSA with the inventory sectors outlined in EPA guidance.

Table 8: Emissions Sources & Activities by Inventory Sector

Source/Activity	GHG Inventory Sector
Electricity Use	Residential Energy, Commercial Energy, Industrial Energy
Natural Gas Use	Residential Energy, Commercial Energy, Industrial Energy
Fugitive Emissions (Pipelines, Oil/Gas Wells)	Process & Fugitive Emissions
Wastewater Treatment	Water & Wastewater
Solid Waste Generation (Landfilled Waste, Compost)	Solid Waste
On-Road Vehicles	Transportation & Mobile Sources
Aviation	
Rail Transportation	
Water Transportation	
Off-Road Vehicles	
Industrial Processes (e.g. steelmaking, concrete production)	Industrial Energy, Process & Fugitive Emissions
HFCs (Refrigerants)	HFCs (Refrigerants)
Agriculture (Fertilizer, Livestock Management)	Agriculture

2.6. Baseline Year

The inventory process requires the selection of a baseline year with which to compare current emissions. As part of the PCAP, the Cleveland-Elyria MSA established 2018 as its baseline year, as it was the most recent year for which the necessary data were available at the time, and it preceded the impacts of COVID-19 pandemic-related mitigation measures during 2020.

2.7. Quantification Methods

A community can quantify GHG emissions in two ways:

- **Measurement-based methodology:** the direct measurement of GHG emissions (from a monitoring system) emitted from a flue of a power plant, wastewater treatment plant, landfill, or industrial facility.

- **Calculation-based methodology:** calculating emissions using activity data and emission factors. This approach employs the following basic calculation:

Activity Data X Emissions Factor = Emissions

The City of Cleveland quantified most emissions sources included in this Cleveland-Elyria MSA inventory through calculation-based methodologies. Activity data refer to the relevant measurement of energy use or other GHG-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Please see previous tables for a detailed listing of the activity data used in composing this inventory.

Cleveland employed established emission factors to convert energy usage or other activity data into total emissions. Emissions factors are expressed in terms of emissions per unit of activity data (e.g., lbs CO_2/kWh of electricity). The City of Cleveland used ICLEI's ClearPath inventory tool to calculate emissions, with a few exceptions, which are outlined below.

Industrial Processes & Product Use (IPPU): Data on IPPU energy use and emissions came from the U.S. EPA's Facility Level Information on GreenHouse gases Tool (FLIGHT). This tool provides facility-level data for entities covered by the Greenhouse Gas Reporting Program (GHGRP), which mandates annual emissions reporting from facilities that directly emit at least 25,000 $MTCO_2e$.[32] During 2022, 21 facilities across the MSA reported to the GHGRP. Staff excluded energy use and emissions from electricity and natural gas consumption to avoid double counting, which left nine facilities that reported emissions from IPPU. Industrial processes generate GHGs several ways, including the conversion of iron ore into metal during steelmaking and the creation of lime from limestone during concrete production. Emissions from industrial product use in the Cleveland-Elyria MSA stem from the use of a variety of non-utility fuels, including blast furnace gas and fuel oils.

HFCs (Refrigerants): City of Cleveland staff downscaled national HFC emissions with 2022 data from the U.S. EPA.[33] Staff estimated HFC emissions per capita, based on 2022 U.S. population data, and then multiplied this per capita emissions value by the population of each county in the MSA.

Agriculture: City of Cleveland staff utilized the methodology developed in partnership with NOACA and ICLEI USA for the PCAP, based on 2022 data from U.S. EPA. and the United States Department of Agriculture (USDA). Staff downscaled agricultural GHG emissions for the State of Ohio to the county level. To do so, staff determined the share of cropland located in Cuyahoga, Geauga, Lake, Lorain, and Medina Counties during 2022, according to the USDA's *Census of Agriculture*. Staff then allocated each county a share of statewide emissions equal to its share of statewide cropland.[34] Sources of emissions included agricultural soil management, enteric fermentation, manure management, urea fertilization, field burning of agricultural residues, and liming.

Tables 9-14 on the following pages break down the GHG inventories for the Cleveland-Elyria MSA and for each of the five counties in the region. Asterisks (*) denote data that staff updated from the 2018 baseline inventory to ensure consistency and accuracy. **Figures 4-8**, in turn, show the distribution of GHG emissions by sector for each county during 2022.

Table 9: 2022 Cleveland-Elyria MSA Inventory Results

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	7,554,518,825	7,503,332,440	kWh	3,490,047	2,775,682	
	Natural Gas	81,428,970*	77,316,450	MMBtu	4,331,927*	4,108,092	
	Propane	1,170,862	1,160,042	MMBtu	72,662	74,469	
	Fuel Oil	710,679	439,171	MMBtu	52,915	32,698	
	Residential Energy Total				7,947,551*	6,990,940	-12.0%
Commercial Energy	Electricity	7,820,324,931	7,061,745,524	kWh	4,059,675	2,577,490	
	Natural Gas	39,476,927*	39,939,787	MMBtu	2,099,640*	2,124,130	
	Commercial Energy Total				6,159,315*	4,701,619	-23.7%
Industrial Energy	Electricity	7,544,519,035	6,744,776,571	kWh	3,948,446	2,504,137	
	Natural Gas	9,567,373*	10,426,661	MMBtu	507,783*	553,390	
	Non-Utility Fuels				2,331,816	1,881,758	
	Industrial Energy Total				6,788,045*	4,939,298	-27.2%
Transportation & Mobile Sources	Gasoline	15,539,152,438	16,221,006,125	VMT	6,303,887	5,906,666	
	Diesel	1,167,907,440	1,171,752,406	VMT	2,018,767	1,963,690	
	Aviation				422,056	422,032	
	Rail Transportation				6,522	160,461	
	Public Transit				37,750	20,815	
	Water Transportation				249,241	207,269	
	Off-Road				106,369	76,245	
	Transportation & Mobile Sources Total				9,144,592	8757178	-4.2%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	2,450,730	2,429,767	Tons	1,422,575	1,370,110	
	Composting	304,938	246,735	Tons	21,233	34,042	
	Combustion of Solid Waste	890	1,838	Tons	308	637	
	Solid Waste Total				1,444,115	1,404,789	-2.7%
Water & Wastewater	Septic Systems				89,524	86,966	
	Combustion of Digester Gas				19	1,305	
	Combustion of Biosolids & Sludges				12,480	10,152	
	N_2O Emissions				14,049	15,390	
	Water & Wastewater Total				116,072	113,813	-1.9%
Process & Fugitive Emissions	Natural Gas Distribution	169,904,636	131,437,016	MMBtu	319,055	232,603	
	Gas and Oil Wells				587,892	587,892	
	Other Process and Fugitive Emissions				1,148,564	1,027,611	
	Process & Fugitive Emissions Total				2,055,510	1,848,105	-10.1%
	HFCs (Refrigerants)				1,014,496	1,140,996	12.5%
	Agriculture				296,577	254,470	-14.2%
	Total Gross Emissions				34,966,243*	30,151,210	-13.8%
	Removals from Forest & Trees Emissions Total				-1,169,371		
	Total Emissions with Sequestration				33,796,872*	28,981,839	-14.2%

Table 10: 2022 Cuyahoga County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	4,220,828,789	4,041,822,934	kWh	1,839,880	1,491,333	
	Natural Gas	55,215,074*	51,930,121	MMBtu	2,936,698*	2,761,815	
	Propane	497,744	526,327	MMBtu	30,889	32,663	
	Fuel Oil	84,972	46,078	MMBtu	6,327	3,431	
	Residential Energy Total				4,813,793*	4,289,242	-10.9%
Commercial Energy	Electricity	5,224,248,774	4,770,754,859	kWh	2,781,715	1,757,422	
	Natural Gas	27,123,308*	27,127,596	MMBtu	1,442,594*	1,445,128	
	Commercial Energy Total				4,224,309*	3,202,550	-24.2%
Industrial Energy	Electricity	5,566,716,131	4,860,439,583	kWh	2,964,066	1,792,250	
	Natural Gas	3,489,616 *	5,183,373	MMBtu	185,210*	275,118	
	Non-Utility Fuels				2,242,573	1,779,750	
	Industrial Energy Total				5,391,849*	3,847,118	-28.6%
Transportation & Mobile Sources	Gasoline	8,763,716,875	8,932,129,598	VMT	3,534,879	3,240,546	
	Diesel	658,621,243	671,278,205	VMT	1,137,775	1,120,922	
	Aviation				422,044	422,031	
	Rail Transportation				6,335	72,191	
	Public Transit				37,750	18,956	
	Water Transportation				202,686	159,484	
	Off-Road				59,275	41,510	
	Transportation & Mobile Sources Total				5,400,744	5,075,639	-6.0%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	1,509,312	1,533,251	Tons	876,110	864,578	
	Composting	185,105	137,661	Tons	12,888	18,993	
	Combustion of Solid Waste		938	Tons		325	
	Solid Waste Total				888,998	883,896	-0.6%
Water & Wastewater	Septic Systems	242,078	242,078	Tons	29,412	28,571	
	Combustion of Digester Gas	83,600	86,600	Service Population	8	38	
	Combustion of Biosolids & Sludges				12,480	10,152	
	N_2O Emissions				11,945	11,321	
	Water & Wastewater Total				53,845	50,082	-7.0%
Process & Fugitive Emissions	Natural Gas Distribution	102,309,483	88,891,205	MMBtu	196,978	156,040	
	Gas and Oil Wells				143,385	143,385	
	Other Process and Fugitive Emissions				918,180	830,389	
	Process & Fugitive Emissions Total				1,258,543	1,129,813	-10.2%
	HFCs (Refrigerants)				614,462	689,406	12.2%
	Agriculture				2,135	1,364	-36.1%
	Total Gross Emissions				22,648,678*	19,169,110	-15.4%
	Removals from Forest & Trees Emissions Total				-233,766		
	Total Emissions with Sequestration				22,414,912*	18,935,344	-15.5%

Table 11: 2022 Geauga County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	480,096,397	458,200,020	kWh	207,535	169,694	
	Natural Gas	2,747,811*	2,734,405	MMBtu	146,147*	145,423	
	Propane	91,272*	88,171	MMBtu	5,664	5,472	
	Fuel Oil	315,188*	196,857	MMBtu	23,468	14,657	
	Residential Energy Total				382,814*	335,245	-12.4%
Commercial Energy	Electricity	335,961,964	281,974,308	kWh	145,228	104,429	
	Natural Gas	10,780,398	1,232,970	MMBtu	57,337*	65,573	
	Commercial Energy Total				202,565*	170,002	-16.1%
Industrial Energy	Electricity	244,082,189	256,001,509	kWh	105,511	94,810	
	Natural Gas	315,578*	242,149	MMBtu	16,749*	12,852	
	Non-Utility Fuels						
	Industrial Energy Total				122,260*	107,662	-11.9%
Transportation & Mobile Sources	Gasoline	783,783,448	825,101,261	VMT	317,712	300,834	
	Diesel	58,994,453	62,009,008	VMT	98,384	103,636	
	Aviation						
	Rail Transportation						
	Public Transit						
	Water Transportation						
	Off-Road				6,484	4,877	
	Transportation & Mobile Sources Total				422,580	409,347	-3.1%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	73,078	77,953	Tons	42,420	43,957	
	Composting	37,702	33,607	Tons	2,625	4,637	
	Combustion of Solid Waste		4	Tons		2	
	Solid Waste Total				45,045	48,595	7.9%
Water & Wastewater	Septic Systems	93,859	93,859	Service Population	11,404	11,078	
	Combustion of Digester Gas						
	Combustion of Biosolids & Sludges						
	N_2O Emissions				30	312	
	Water & Wastewater Total				11,434	11,389	-0.4%
Process & Fugitive Emissions	Natural Gas Distribution	3,652,561	4,125,566	MMBtu	7,368	7,189	
	Gas and Oil Wells				134,546	134,546	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				141,914	141,735	-0.1%
	HFCs (Refrigerants)				46,345	52,368	13.0%
	Agriculture				66,863	58,335	-12.8%
	Total Gross Emissions				1,441,821*	1,334,679	-7.4%
	Removals from Forest & Trees Emissions Total				-361,018		
	Total Emissions with Sequestration				1,080,803*	973,661	-9.9%

Figure 4: 2022 Cuyahoga County GHG Emissions by Sector

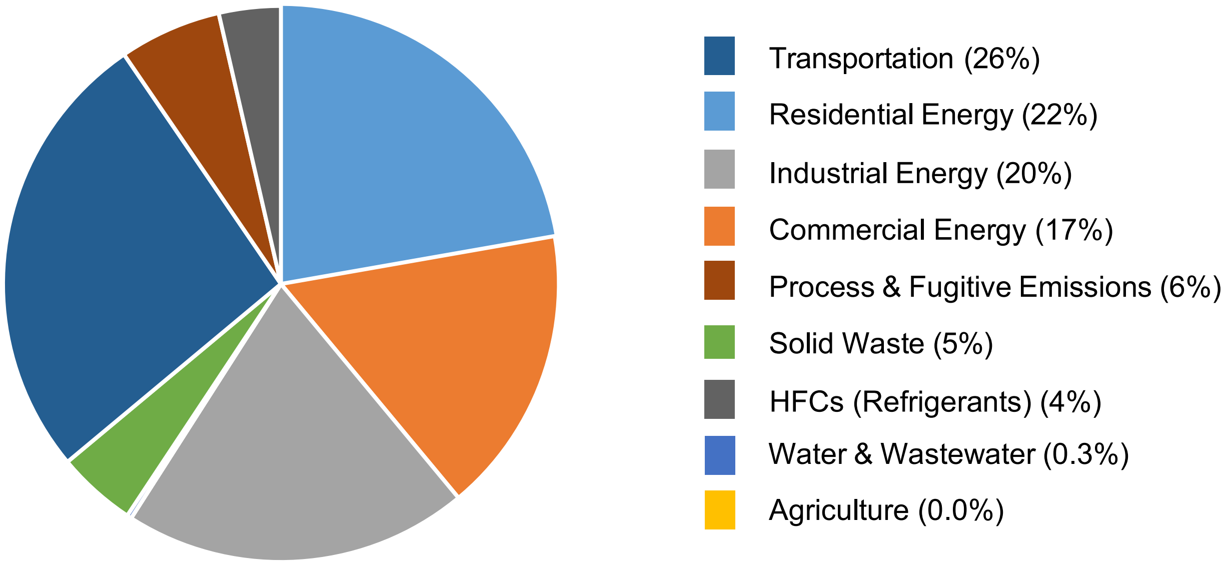


Figure 5: 2022 Geauga County GHG Emissions by Sector

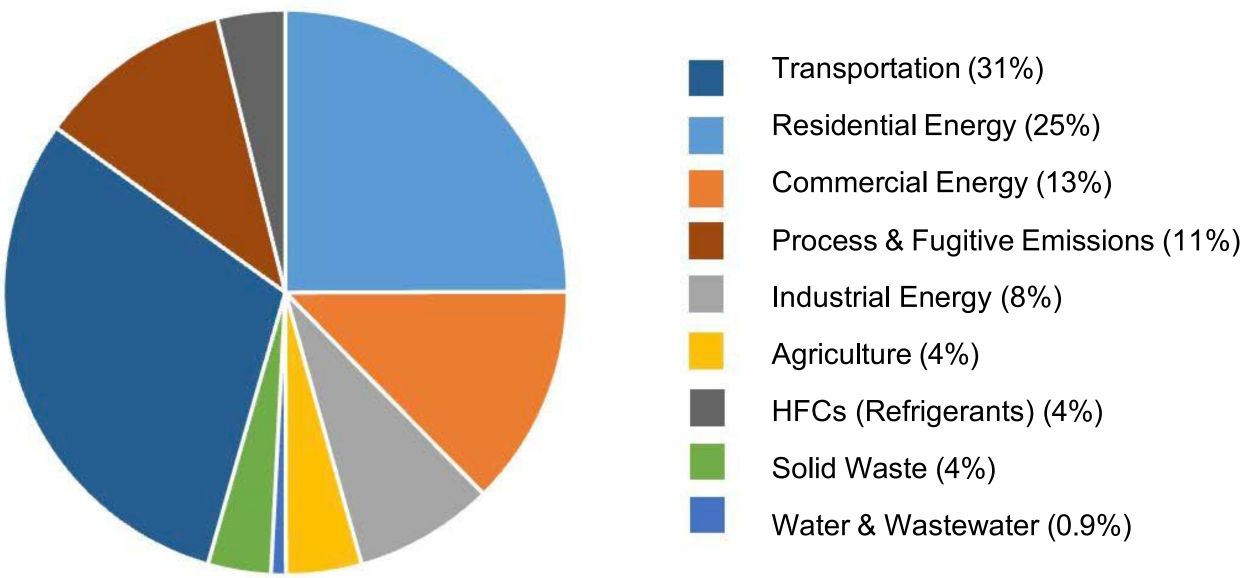


Table 12: 2022 Lake County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	906,150,299	883,041,980	kWh	506,729	334,437	
	Natural Gas	8,351,461*	7,930,031	MMBtu	444,185*	421,745	
	Propane	85,581	94,451	MMBtu	5,311	5,862	
	Fuel Oil	102,668	67,813	MMBtu	7,644	5,049	
	Residential Energy Total				963,869*	767,092	-20.4%
Commercial Energy	Electricity	967,757,939	839,859,052	kWh	539,165	318,282	
	Natural Gas	3,371,014*	3,722,638	MMBtu	179,292*	197,982	
	Commercial Energy Total				718,457*	516,264	-28.1%
Industrial Energy	Electricity	577,753,228	548,761,691	kWh	319,314	206,946	
	Natural Gas	559,026*	1,248,587	MMBtu	29,670*	66,268	
	Non-Utility Fuels				84,850	96,603	
	Industrial Energy Total				433,834*	369,817	-14.8%
Transportation & Mobile Sources	Gasoline	1,775,729,312	1,698,197,785	VMT	727,972	853,752	
	Diesel	133,451,715	127,625,014	VMT	231,624	215,316	
	Aviation				6		
	Rail Transportation					28,438	
	Public Transit					1,859	
	Water Transportation				33,795	30,342	
	Off-Road				14,002	9,796	
	Transportation & Mobile Sources Total				1,007,399	1,139,549	13.1%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	238,705	275,550	Tons	138,561	155,378	
	Composting	38,372	30,297	Tons	2,672	4,180	
	Combustion of Solid Waste			Tons			
	Solid Waste Total				141,233	159,559	13.0%
Water & Wastewater	Septic Systems	119,913	119,913	Service Population	14.569	14,153	
	Combustion of Digester Gas	55,567	149,642	Service Population	3	9	
	Combustion of Biosolids & Sludges						
	N_2O Emissions				826	1,187	
	Water & Wastewater Total				15.398	15,349	-0.3%
Process & Fugitive Emissions	Natural Gas Distribution	11,734,203	12,884,994	MMBtu	23,671	22,415	
	Gas and Oil Wells				65,436	65.436	
	Other Process and Fugitive Emissions				230,384	197.222	
	Process & Fugitive Emissions Total				319,491	285,074	-10.8%
	HFCs (Refrigerants)				113,001	127,409	12.8%
	Agriculture				12,545	12,112	-3.5%
	Total Gross Emissions				3,725,227	3,392,180	-8.9%
	Removals from Forest & Trees Emissions Total				-165,452		
	Total Emissions with Sequestration				3,559,775	3,226,728	-9.4%

Table 13: 2022 Lorain County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	1.173.965.126	1,307,302,496	kWh	566.728	475,290	
	Natural Gas	9.562.577*	9,361,754	MMBtu	508.601*	494,039	
	Propane	275.145	251,200	MMBtu	17.075	15,589	
	Fuel Oil	74.104	46,823	MMBtu	5.518	3,486	
	Residential Energy Total				1.097.923*	988,404	-10.0%
Commercial Energy	Electricity	855.797.279	764,282,012	kWh	391.673	253.28	
	Natural Gas	4.892.982*	4,954,905	MMBtu	260.241*	263.518	
	Commercial Energy Total				651.914*	516.799	-20.7%
Industrial Energy	Electricity	704,467,502	646,218,556	kWh	313.334	525.078	
	Natural Gas	3,536,054*	2,474,828	MMBtu	187.674*	131.35	
	Non-Utility Fuels				4.393	5.405	
	Industrial Energy Total				505.401*	388.833	-23.1%
Transportation & Mobile Sources	Gasoline	2,367,586,799	2,327,756,398	VMT	973.673	857,294	
	Diesel	177,931,690	174,938,364	VMT	309.532	295,379	
	Aviation				6	1	
	Rail Transportation				187	50,351	
	Public Transit						
	Water Transportation				12,760	17.443	
	Off-Road				17,242	12,854	
	Transportation & Mobile Sources Total				1,313,400	1,233,321	-6.1%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	406,699	337,393	Tons	237,818	190,251	
	Composting	33,902	41,085	Tons	2,361	5,669	
	Combustion of Solid Waste	890	890	Tons	308	309	
	Solid Waste Total				240,487	196,228	-18.4%
Water & Wastewater	Septic Systems	171,461	171,461	Service Population	20,832	20,237	
	Combustion of Digester Gas	113,844	118,000	Service Population	7	90	
	Combustion of Biosolids & Sludges						
	N_2O Emissions				1,141	2,160	
	Water & Wastewater Total				21,980	22,488	2.3%
Process & Fugitive Emissions	Natural Gas Distribution	35,634,279	16,279,432	MMBtu	61,824	30,059	
	Gas and Oil Wells				62,566	62,566	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				124,390	92,625	-25.5%
	HFCs (Refrigerants)				152,041	171,773	13.0%
	Agriculture				120,144	94,931	-21.0%
	Total Gross Emissions				4,227,680*	3,705,403	-12.4%
	Removals from Forest & Trees Emissions Total				-206,873		
	Total Emissions with Sequestration				4,020,807*	3,498,530	-13.0%

Figure 6: 2022 Lake County GHG Emissions by Sector

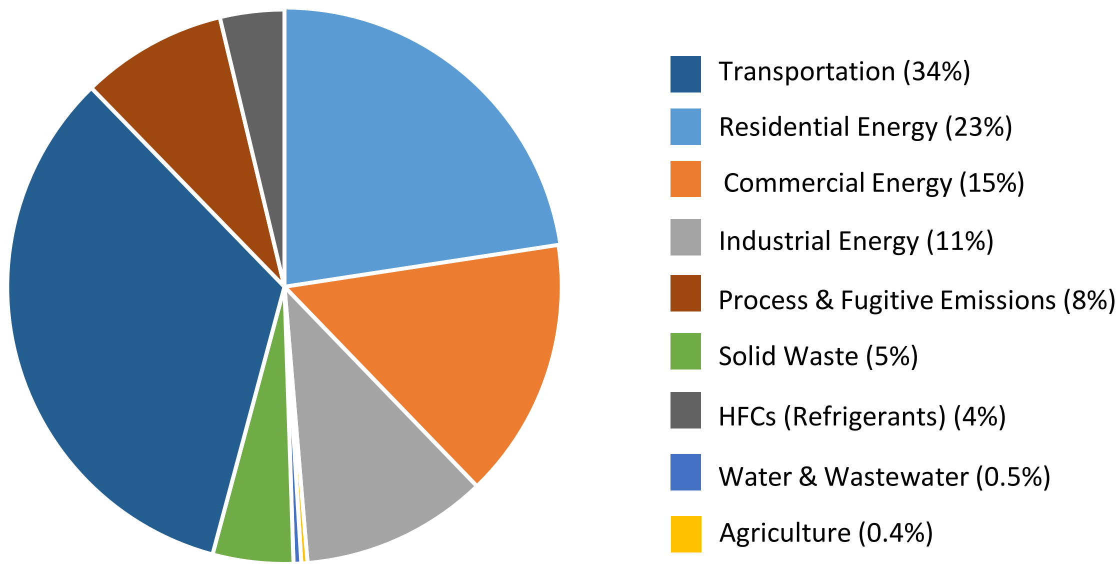


Figure 7: 2022 Lorain County GHG Emissions by Sector

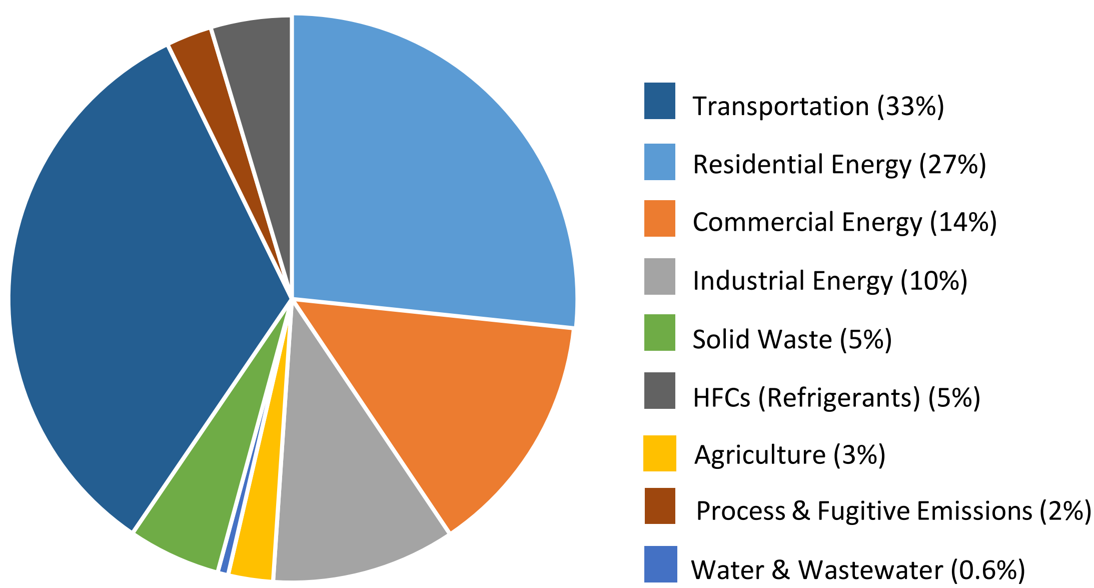
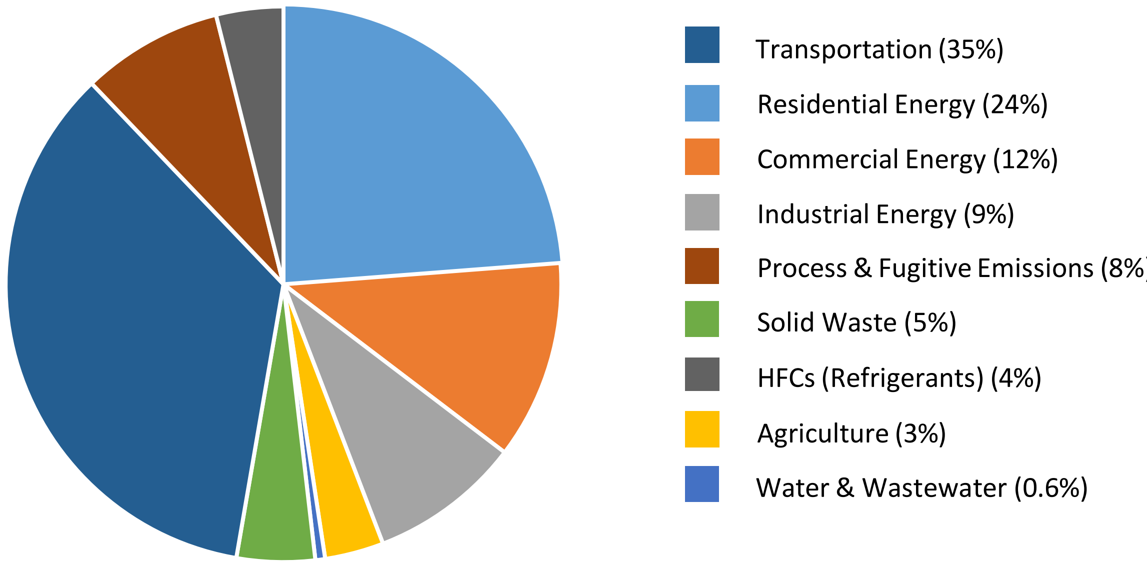


Table 14: 2022 Medina County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Residential Energy	Electricity	773,478,214	812,965,010	kWh	369.176	304,929	
	Natural Gas	5,552,047*	5,360,139	MMBtu	296.296*	285,070	
	Propane	221,121	199,892	MMBtu	13.723	14,883	
	Fuel Oil	133,746	81,559	MMBtu	9.958	6,075	
	Residential Energy Total				689.152*	610,957	-11.3%
Commercial Energy	Electricity	436,558,974	404,875,293	kWh	201,894	144,077	
	Natural Gas	3,011,584*	2,856,678	MMBtu	160,176*	151,928	
	Commercial Energy Total				362,070*	296,004	-18.2%
Industrial Energy	Electricity	451,505,985	423,355,232	kWh	246,221	158,054	
	Natural Gas	1,667,099*	1,277,725	MMBtu	88,480*	67,815	
	Non-Utility Fuels						
	Industrial Energy Total				334,701*	225,869	-32.5%
Transportation & Mobile Sources	Gasoline	1,848,336,004	1,808,330,158	VMT	749,651	654,240	
	Diesel	138,908,339	135,901,815	VMT	241,452	228,436	
	Aviation						
	Rail Transportation					9,436	
	Public Transit						
	Water Transportation						
	Off-Road				9,366	7,208	
	Transportation & Mobile Sources Total				1,000,469	899,321	-10.1%

Sector	Fuel or Source	Usage		Unit	Emissions ($MTCO_2e$)		Percent Change
		2018	2022		2018	2022	
Solid Waste	Waste Generation	219,936	205,620	Tons	127,666	115,946	
	Composting	9,857	9,857	Tons	686	564	
	Combustion of Solid Waste		6	Tons		2	
	Solid Waste Total				128,352	116,512	-9.2%
Water & Wastewater	Septic Systems	109,535	109,535	Service Population	13,308	12,928	
	Combustion of Digester Gas	25,000	82,600	Service Population		1,168	
	Combustion of Biosolids & Sludges						
	N_2O Emissions				107	409	
	Water & Wastewater Total				13,415	14,505	8.1%
Process & Fugitive Emissions	Natural Gas Distribution	16,574,163	9,255,819	MMBtu	29,214	16,900	
	Gas and Oil Wells				181,958	181,958	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				211,172	198,858	-5.8%
	HFCs (Refrigerants)				88,646	100,039	12.9%
	Agriculture				94,890	87,728	-7.5%
	Total Gross Emissions				2,922,867	2,549,792	-12.8%
	Removals from Forest & Trees Emissions Total				-202,262		
	Total Emissions with Sequestration				2,720,605	2,347,530	-13.7%

Figure 8: 2022 Medina County Emissions by Sector

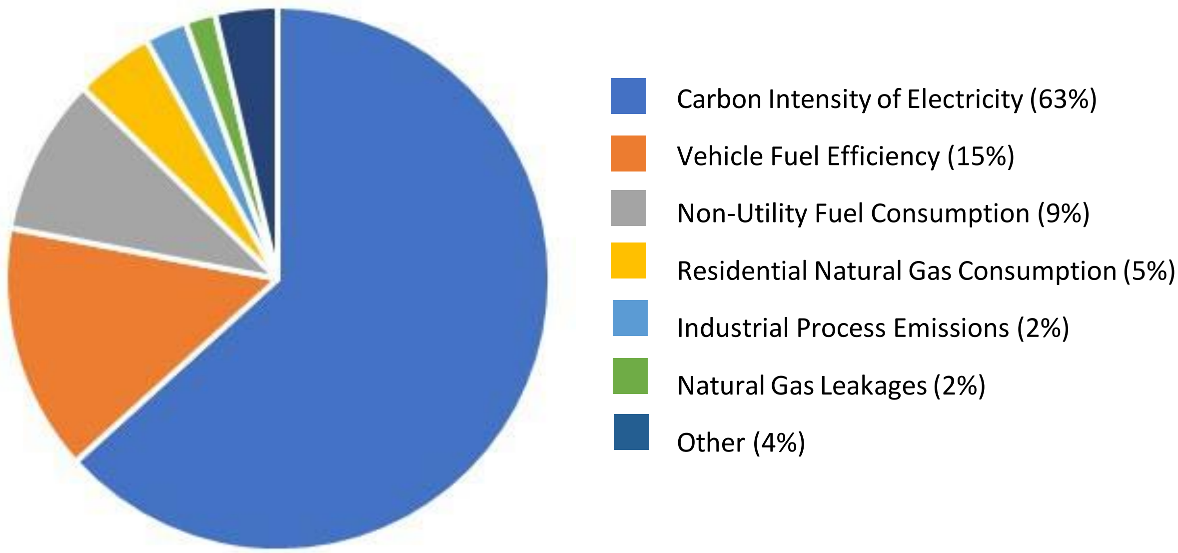


2.8. Cleveland-Elyria MSA GHG Emissions Trends: 2018 to 2022

GHG emissions in 2022 were 14.2% lower than during the baseline year of 2018. The largest sectoral decreases occurred for Industrial Energy (-27.2%), Commercial Energy (-23.7%), and Residential Energy (-12.0%). The only sector in which emissions increased was HFCs (Refrigerants) (12.5%). Per capita emissions fell by 14.5%, to 14.5 $MTCO_2e$ in 2022. Accounting for inflation, regional gross domestic product (GDP) increased by 6% to $138.3 billion from $130.5 billion, in 2017 dollars. As a result, $MTCO_2e$ per million dollars of GDP fell by 18.6%, demonstrating the decoupling of economic growth from GHGs.

Figure 9 identifies the major sources of the observed GHG reductions from 2018 to 2022. The average carbon intensity of electricity in Northeast Ohio fell 26.5%, from 1,106 pounds per megawatt hour (lbs/MWh) to 813 lbs/MWh. This reduction in carbon intensity from grid electricity reduced GHG emissions by 3.76 MMTCO2e (63.3%). The fuel efficiency of gasoline and diesel vehicles improved by 17.2% and 1.6%, respectively, which accounted for 14.8% of the total reduction in emissions. This reduction occurred despite a 4.1% increase in vehicle miles traveled (VMT). Industry made up 11.9% of the observed reduction, due to lower non-utility fuel use (9.3%) and reduced industrial process emissions (2.5%). The remaining reductions were due to decreased residential natural gas usage (4.6%), reduced natural gas leakages (1.8%), and other sources (3.7%).

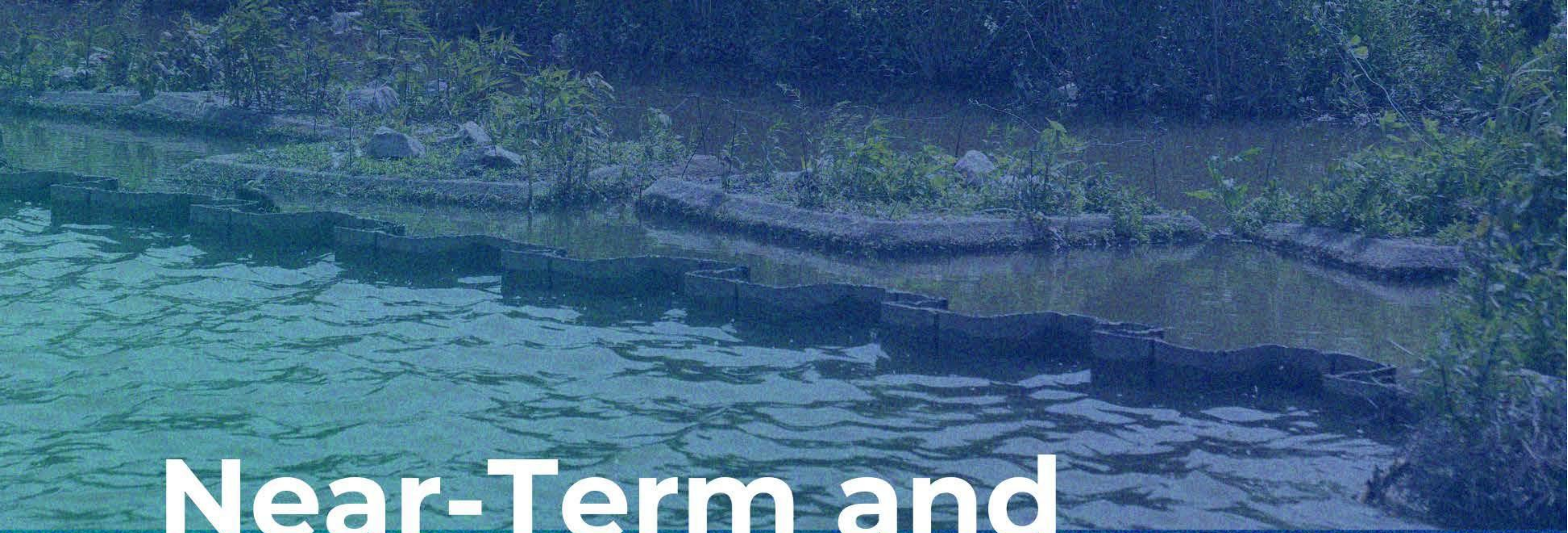
Figure 9: Sources of GHG Emissions Reductions in Cleveland Elyria MSA, 2018 to 2022



2.9. GHG Inventory Next Steps

Going forward, the Cleveland-Elyria MSA will update this GHG inventory every two years to assess the progress of implementing the actions outlined in this CCAP. The next inventory update will be included in the CPRG Status Report, which NOACA will deliver to U.S. EPA during July 2027.

Near-Term and Long-Term GHG Reduction Targets



3. Near-Term and Long-Term GHG Reduction Targets

In the CCAP guidance, U.S. EPA calls for MSAs to establish economy-wide near-term and long-term emissions reduction targets which "should not be inconsistent with the United States' formal commitments to reduce emissions 50-52% relative to 2005 levels by 2030 and to reach net zero emissions by 2050."[35] Additionally, EPA guidance recommends that MSAs account for existing local emissions targets and consider whether potential targets balance technical and economic feasibility with science-based reduction trajectories.

Based on this guidance, the City of Cleveland and NOACA evaluated potential near- and long-term emissions reduction targets that were at least as ambitious as the U.S.'s Nationally Determined Contribution (NDC). As part of this evaluation process, the City of Cleveland and NOACA examined potential targets based on the following criteria:

- How well do they align with existing emissions reduction targets within the Cleveland-Elyria MSA?
- How well do they reflect the best available science on climate change?
- How closely do they match observed and projected trends in emissions reductions within the Cleveland-Elyria MSA?
- What is the ratio between the costs of achieving the targets and the co-benefits of the emissions reductions?

Based on these factors, the NOACA Board of Directors voted unanimously at its December 2024 meeting to adopt the following targets:

- **Near-Term GHG Reduction Target:** 49% reduction by 2030 from 2018 levels (56-62% reduction from estimated 2005 levels)
- **Long-Term GHG Reduction Target:** Net zero emissions by 2050

3.1. Target Alignment

As discussed in Chapter 1, there is a long and robust history of climate action planning within the Cleveland-Elyria MSA. Several communities within the MSA have adopted ambitious climate targets, and the City of Cleveland and NOACA took these local commitments into consideration while evaluating potential GHG reduction targets.

Local GHG reduction targets include:

- 75% reduction by 2030 (from 2007 levels): City of Oberlin
- 63.3% reduction by 2030 (from 2018 levels): City of Cleveland and Cuyahoga County
- 50-52% reduction by 2030 (from 2005 levels): City of Lakewood
- 49% reduction by 2030 (from 2018 levels): NOACA (Cleveland-Elyria MSA PCAP)
- 30% reduction by 2030 (from 2010 levels): Cities of Cleveland Heights, East Cleveland, Euclid, Fairview Park, Garfield Heights, Lorain, Maple Heights, Shaker Heights, Solon, South Euclid, and University Heights; Villages of Moreland Hills and Oakwood

As this list shows, there is a wide range of near-term targets across the MSA, though nearly all of these communities have committed to achieve net zero emissions by 2050. The targets that the NOACA Board adopted for this CCAP fall squarely within this range and align with the targets the region previously identified in its PCAP.

3.2. Reflect Climate Change Science

As science has become clearer and the likely impacts of climate change become more alarming, the need for communities to take aggressive climate action is abundantly clear. The Science-Based Targets Network (SBTN) works with communities across the world to set climate targets that reflect this evidence. These science-based targets (SBTs) are “measurable, actionable, and time-bound objectives, based on the best available science, that allow actors to align with Earth’s limits and societal sustainability goals.”[36] Adopting SBTs is best practice for cities that are committed to climate action. While there are different approaches to establishing SBTs, they all require communities to adopt targets at least as ambitious as their country’s NDC. Accordingly, by following CPRG guidance, the Cleveland-Elyria MSA has established a SBT for the region.

3.3. Match Emissions Reduction Trends

The 2030 targets that the U.S. adopted are based on a 2005 baseline. Because the Cleveland-Elyria MSA uses 2018 as its GHG inventory baseline year, it is difficult to determine whether the MSA’s near-term emissions targets accord with the NDC. To address this challenge, the City of Cleveland developed different approaches to “backcast” (i.e., forecast data backwards in time) GHG emissions.[37] Staff based these estimates upon 2018 and 2022 regional GHG inventory data and 1990-2022 GHG inventory data for the U.S. and the State of Ohio.[38]

Cleveland used two main approaches. First, MOS staff calculated the MSA share of Ohio GHG emissions in 2018 and 2022 and applied this factor to 2005 statewide GHGs. Second, staff calculated per capita GHG emissions for the MSA and for the State of Ohio in 2018 and 2022. Staff then quantified the ratio of per capita emissions in the MSA to per capita emissions for the State during 2018 and 2022 before applying these ratios to per capita emissions for the State in 2005.

These approaches provide a reasonable band of estimated emissions for the MSA during 2005, ranging from a low of 40.53 $MMTCO_2e$ to a high of 46.83 $MMTCO_2e$. Based on these estimates, the Cleveland-Elyria MSA cut emissions by an estimated 25.6-35.6% from 2005 to 2022. During this period, annual GHG emissions fell by 0.9%, 1.5%, and 1.5-2.1% nationally, in the State of Ohio, and in the MSA, respectively. This gap has increased in recent years; from 2018 to 2022, emissions fell more than twice as fast in the Cleveland-Elyria MSA (3.4% per year) than in the U.S. (1.5%) or State of Ohio (1.2%).

Thus, the MSA’s near-term target is more ambitious than the national goal, as the region has cut emissions faster than the nation.

3.4. Cost-Benefit Ratio of Targets

To inform the decision further, the City of Cleveland analyzed the potential public health benefits of different SBTs. Staff utilized the U.S. EPA's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool to model the air quality, public health, and economic benefits of different emissions reductions scenarios.[39] Staff analyzed five potential reduction targets, outlined in **Table 15**, along with 100% reduction (representing net zero emissions).[40]

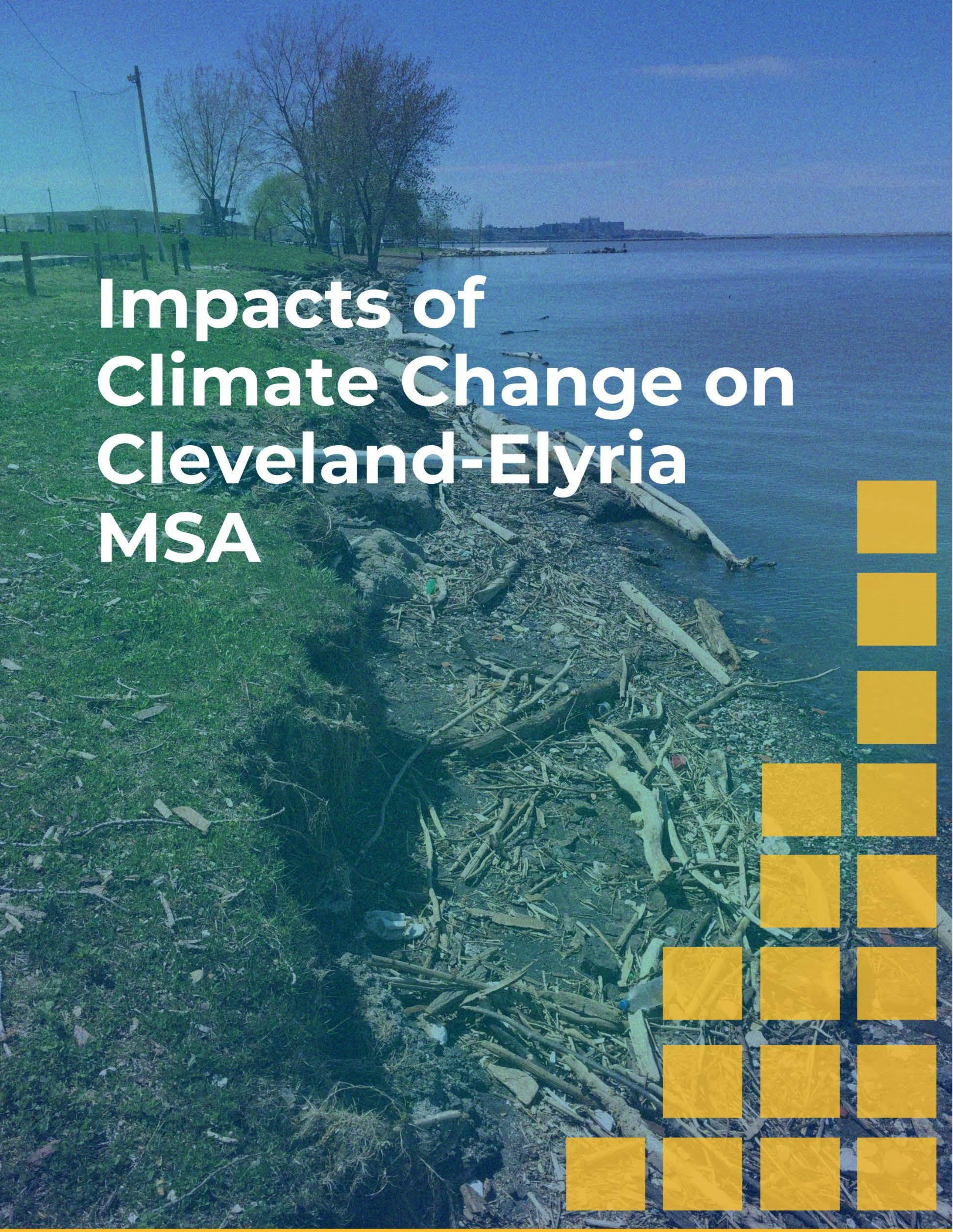
Table 15: Near-Term Emissions Reduction Targets Evaluated for Cleveland-Elyria MSA

Option	2005 Emissions ($MMTCO_2e$)	Percent Reduction from 2005 Emissions	2018 Emissions (MMtCO2e)	Percent Reduction from 2018 Emissions	Projected 2030 Emissions $MMTCO_2e$)	Annual Rate of Reduction
Option 1	40.53 - 46.83	43.8-51.4%	34.97	34.80%	22.78	3.40%
Option 2		58.0-63.6%		51.30%	17.04	6.90%
Option 3		**56.0-61.9%**		**49.00%**	**17.84**	**6.40%**
Option 4		51.1-57.6%		43.3-44.7%	19.32-19.84	5.1-5.4%
Option 5		68.3-72.6%		63.30%	12.84	10.10%

While there is a near-linear relationship between total public health benefits and GHG target ambition (i.e., benefits increase in tandem with the targets), the ratio between these co-benefits and the rate of annual emissions reductions that are required differs across potential targets. The target identified in the PCAP – a 49% reduction by 2030 from 2018 levels – had the best cost-benefit ratio of the targets evaluated.

According to this evaluation, the MSA has adopted near- and long-term GHG reduction targets that align with U.S. EPA guidance, which calls for targets that accord with local goals and policies and that balance ambition with practicality.

Impacts of Climate Change on Cleveland-Elyria MSA



4. Impacts of Climate Change on Cleveland-Elyria MSA

Human activities have warmed the atmosphere, the oceans, and land. This warming is largely due to the release of GHGs, dominated by the burning of fossil fuels. The earth will continue to warm as humans continue to emit GHGs into the atmosphere.

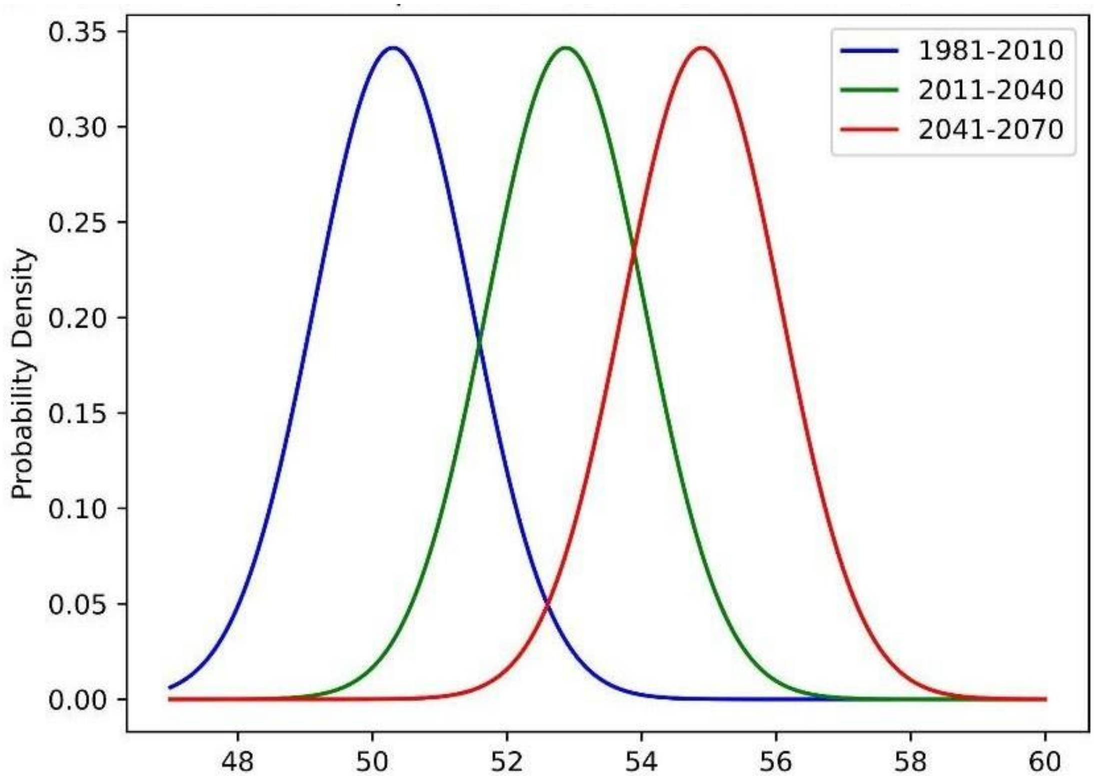
In 2015, countries around the world signed the Paris Agreement, in which they agreed to take action to hold increases in global average temperatures well below 2˚C and to pursue the goal of keeping this increase to under 1.5˚C.[41] According to the IPCC, human activities "have unequivocally caused global warming" of 1.1°C above pre-industrial levels (range of 0.8-1.3°C).[42] Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate, with global temperatures exceeding 1.5°C above pre-industrial levels for the first time in 2024.[43] Warming due to emissions from human activities will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea-level rise. Immediate action to reduce GHG emissions is essential to limit the impacts of climate change, as "every increment of global warming will intensify multiple and concurrent hazards."[44] According to a recent study, each 0.1°C of additional global warming pushes another 100 million people into unprecedented and life threatening high temperatures.[45]

4.1. Observed Impacts of Climate Change in Cleveland-Elyria MSA

While the Paris Agreement focuses on global average surface temperatures, this number only begins to tell the story of the impact of climate change. Historical data indicate that Northeast Ohio has warmed by approximately 3.5°F over the past century, nearly twice as fast as the world.[46] If this trend holds, it indicates that if the global mean temperature increases by 2°C (3.6°F), then Northeast Ohio's mean temperature will increase by about 3.4°C (6.1°F). Moreover, if the global mean temperature increases by 3.2°C, as is expected based on current policies to address climate change, then Northeast Ohio could warm by about 5.4°C (9.8°F).[47]

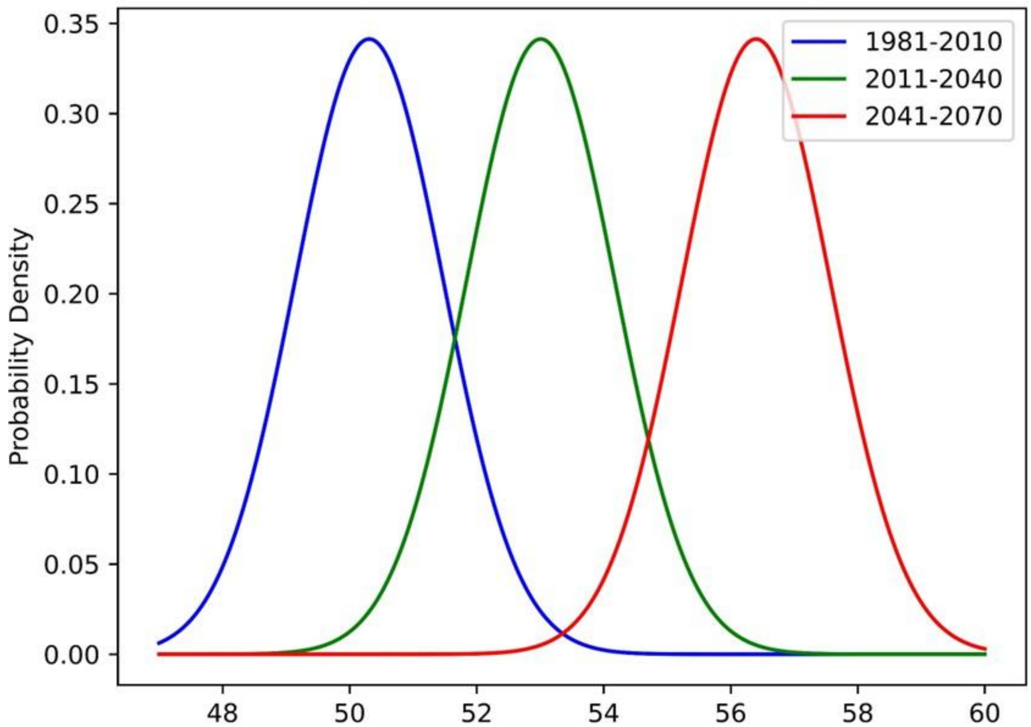
Because average temperatures are just that, they can conceal significant fluctuations and changes in extremes. **Figure 10**, below, illustrates this effect. The blue curve depicts the probability distribution of average annual temperatures in the MSA from 1981 to 2010. Most years clustered around the overall average of 49.7°F, but some years were colder; 1980 only averaged 48°F, for example. As the region warms due to GHG emissions, this temperature curve will shift to the right, causing more warm years and fewer cold years. The green and red curves plot the distribution of average annual temperatures for the MSA for 2011-2040 and 2041-2070, respectively, under a lower warming scenario.[48]

Figure 10: Distribution of Annual Mean Temperatures in Low Warming Scenario



This demonstrates the fundamental shift of the region's climate under even relatively modest warming. The changes are even more dramatic - and dire - in the higher emissions scenario illustrated in **Figure 11**.[49] In this scenario, the average year is warmer than even the warmest years in the region's history. The implications are clear: the Cleveland-Elyria MSA is warming rapidly, which presents significant threats to the people and systems of the region.

Figure 11: Distribution of Annual Mean Temperatures in High Warming Scenario



These changes have broad implications. They range from an increased need for air conditioning in the summer and a decreased need for heating in the winter, to changes in the length of the growing season. As the earth warms, moisture transport into weather systems also increases. For each 1°C of warming, the atmosphere can hold approximately 7% more moisture, which may lead to more extreme precipitation events. And, because the climate is a global system, the impacts of global warming are not confined to one region. Climate change may have doubled the likelihood of extreme fire weather conditions in Eastern Canada during 2023, which led to the worst air quality in the region's recorded history.[50]

4.2. Priority Climate Hazards and Project Impacts in Cleveland-Elyria MSA

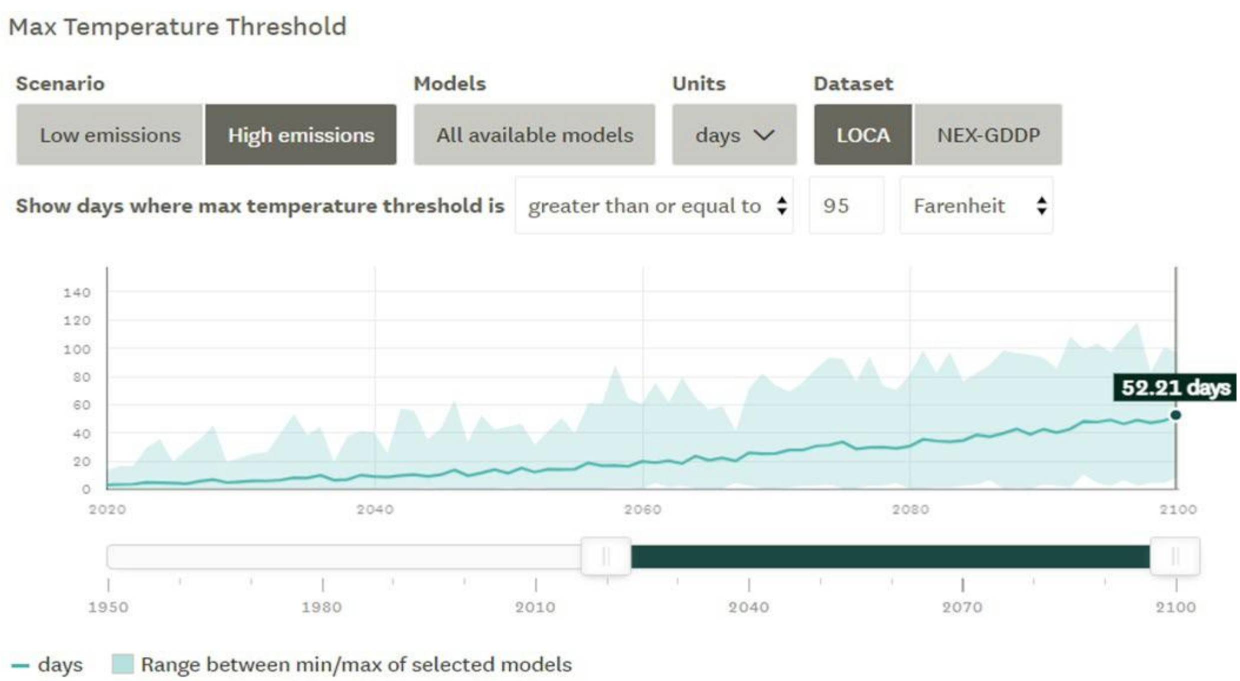
During 2022 and 2023, NOACA developed a CRVA for the MSA. NOACA partnered with ICLEI USA to review available resources and localized climate projections to learn which hazards are most likely to affect the five counties, as well as to evaluate the seriousness of their impacts. Based upon this literature and extensive engagement with stakeholders, NOACA staff determined extreme heat, heavy rainfall and flooding, and severe convective storms as primary hazards of focus to assess regional vulnerability. Based on feedback from the public during its 2023 community outreach efforts, NOACA added air quality issues/pollution to its list of priority hazards. The City of Cleveland conducted its own CRVA in 2023-2024, which complements the NOACA assessment.[51] Both reviews included extensive stakeholder and public engagement processes (see Chapter 1). **Table 16** identifies the priority climate hazards identified through these processes.

Table 16: Priority Climate Hazards for Cleveland-Elyria MSA

NOACA CRVA	City of Cleveland CRVA
Extreme Heat	Poor Air Quality
Heavy Rainfall & Flooding	Extreme Heat
Severe Convective Storms	Heavy Precipitation & Flooding
Air Quality Issues/Pollution	Severe Summer Storms

Extreme Heat: The Cleveland-Elyria MSA will face more extreme heat (heat waves and an increase in the number of extreme hot days) combined with increased humidity. From 1961 to 1990, the region experienced less than one day per year (on average) where temperatures exceeded 95°F. By 2100, temperatures may reach 95°F in the Cleveland-Elyria MSA as many as 52 days each year.[52] Both the frequency and duration of heat waves will increase significantly; by 2050, the risk of a three-day heatwave nearly doubles to 80% per year. Warm nights, when the low temperature fails to drop below 75°F, people and wildlife are unable to have an opportunity to cool off from daytime temperatures. These situations are particularly dangerous to health and well-being; by 2100 there are likely to be 52 warm nights annually (**Figure 12**).[53]

Figure 12: Projection for Number of 95°F Days per Year for Cleveland-Elyria MSA



In areas where there is a higher concentration of older housing stock (e.g. First Suburbs like East Cleveland, which has a high concentration of LIDACs), most houses are not built for the heating and cooling needs our region will face in coming years. As low income populations tend to reside in older, less energy efficient housing stock, this will exacerbate existing vulnerabilities.

Heavy Precipitation & Flooding: The MSA will also face increased heavy precipitation, severe storms, and flooding. Annual precipitation has risen by 10.5 inches (29.6%) from 1951 to 2023.[54] A larger share of this precipitation is also falling during the most severe storms. Since the 1950s, the amount of precipitation falling during the heaviest 1% of events has risen by 45%, which places an additional strain on the region's stormwater infrastructure and increases the risk of flash flood events.[55] The average number of days with more than one inch of precipitation has increased in all five MSA counties since 1981. The smallest increase during that period was 0.8 days per decade in Lorain County, while the largest increase was 1.42 days per decade in Cuyahoga County.[56]

Future changes in flood risk are complex to project due to the variety of factors involved in flooding. Climatic changes in rainfall and snowmelt are key drivers. However, other human and natural factors, including seasonality, urbanization patterns, land use change, dams, and stormwater and agricultural management practices are also highly relevant.[57] According to Flood Factor, a probabilistic flood model developed by the First Street Foundation, the Cleveland-Elyria MSA counties fall in the minor to moderate range for flood risk.[58] The county breakdown is shown in **Table 17**. Risk to critical infrastructure, a category that includes facilities like airports, police stations, wastewater treatment facilities, and power plants, appears to be the main driver.

Table 17: Flood Factor Rankings for Cleveland-Elyria MSA Counties

County	Overall Flood Risk	Top Risk Categories & Level
Cuyahoga	Moderate	Critical Infrastructure (Major)
Geauga	Minor	Social Facilities (Moderate)
Lake	Moderate	Critical Infrastructure (Major)
Lorain	Minor	Commercial (Moderate), Critical Infrastructure (Moderate)
Medina	Minor	Commercial (Moderate), Critical Infrastructure (Moderate)

Severe Summer Storms: Strong convective storms, including thunderstorms and windstorms, produce powerful winds, lightning, hailstones, tornadoes, and flash flood events that can damage property and affect people. These storms, also termed "severe summer storms," are currently one of the most harmful forms of climate hazards in Northeast Ohio. From 2014 to 2023, at least 255 summer storm events have caused property damage in the region. In total, these storms have caused $12.9 million in property damage, two deaths, and six injuries.[59] Most recently, a cluster of tornadoes touched down on August 6, 2024, which caused severe damage and left hundreds of thousands of residents without power for days.[60]

Research suggests these types of storms will become more frequent and intense due to a changing climate.[61] The amount of rain falling in these extreme events will continue to increase in the coming decades. This will raise the risks of damaging flash flood events. Furthermore, climate models suggest that average wind speeds may increase across all counties in the region by 2050, which could lead to a rise in the intensity of winds during summer storms.[62]

Poor Air Quality: Poor air quality has emerged as a top climate hazard of concern for the Cleveland-Elyria MSA. The region continues to face issues with ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$). A seven-county area, including the entire Cleveland-Elyria MSA, is currently a serious nonattainment region for the 2015 National Ambient Air Quality Standard (NAAQS) for O_3, and Cuyahoga County does not meet the US EPA's 2024 NAAQS for $PM_{2.5}$.[63] Because climatic conditions affect the formation and transport of these pollutants, climate change threatens to undermine or even reverse some of the region's air quality improvements. U.S. EPA projects that O_3 levels in the Midwest may increase by 1-5 parts per billion (ppb) and up to 10 ppb by 2050 and 2100, respectively.[64]

Increased precipitation may reduce $PM_{2.5}$ levels within Northeast Ohio, as US EPA forecasts that annual $PM_{2.5}$ will decline by 1.5 micrograms per cubic meter ($\mu g/m^3$) in the Midwest.[65] However, this reduction is not guaranteed; under higher warming scenarios, $PM_{2.5}$ levels actually increase in Northeast Ohio.[66] This outcome may be a product of increased wildfire activity outside of Northeast Ohio, as the region experienced during the summer of 2023. Due to persistent wildfires throughout Canada, Northeast Ohio endured its highest and second highest daily $PM_{2.5}$ levels ever on June 28 and 29, 2023 (see **Figure 13**).

Figure 13: Canadian Wildfire Smoke in Cleveland-Elyria MSA, June 2023

June 28th, 2023 at 6:55am - 302 AQI

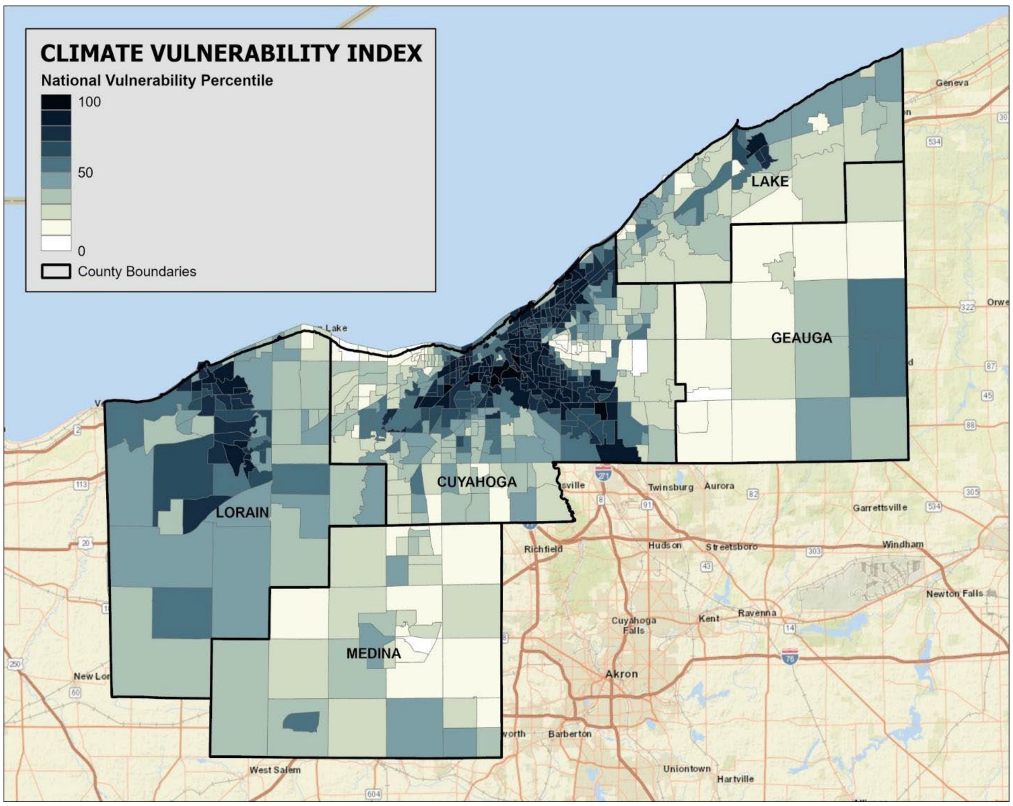
June 30th 2023 at 9:42am - 47 AQI

4.3. Vulnerable Population Groups

Climate vulnerability refers to one's "propensity or predisposition…to be affected adversely by hazards."[67] Vulnerability encompasses exposure, sensitivity, potential impacts, and adaptive capacity. Certain groups are more susceptible to climate hazards due to (1) their exposure to stresses associated with environmental and social changes, and (2) their limited capacity to adapt or reduce exposure to such harms.[68] Both social and place-based factors affect this underlying susceptibility. Social vulnerability encompasses "those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond."[69] Place inequalities, in turn, are tied to "characteristics of communities and the built environment, such as the level of urbanization, growth rates, and economic vitality."[70] While climate vulnerable population groups are spread across the MSA, they are largely concentrated in Cuyahoga County, particularly within the City of Cleveland.

Figure 14 displays the national percentile rank for each Census tract according to the Climate Vulnerability Index (CVI).[70b] Top ranking tracts are home to large shares of vulnerable population groups, including children under the age of 18, the elderly, households without access to vehicles, outdoor workers, people living with disabilities and health conditions, people with less than a high school diploma, racial minorities, and people with limited English proficiency.

Figure 14: Climate Vulnerability Index Scores by Census Tract



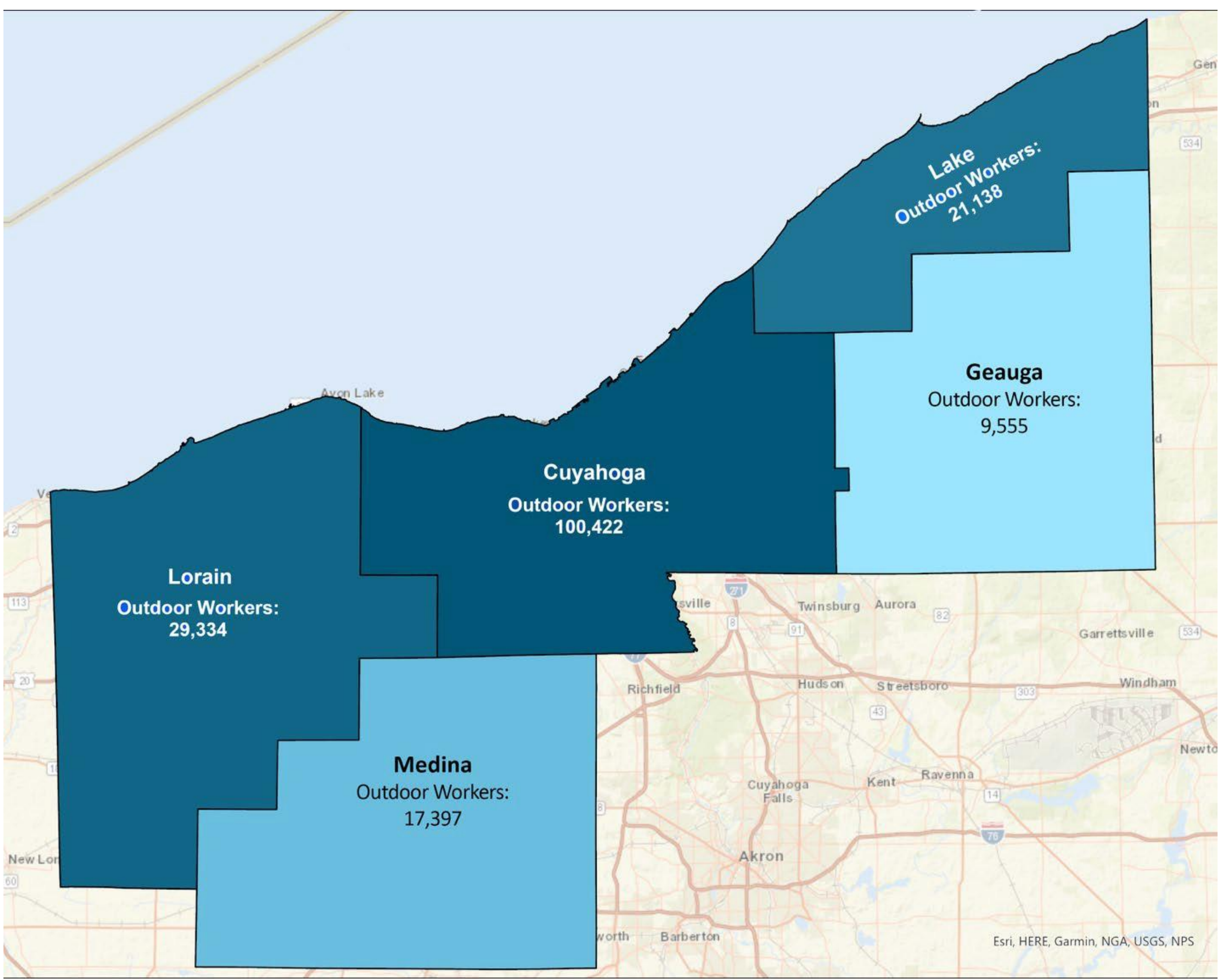
As the City of Cleveland's CRVA shows, outdoor workers are among the most climate vulnerable groups in the MSA. Given the nature of their work, they are particularly vulnerable to increased temperatures, which expose them to financial and physical harm. Outdoor workers are evenly distributed, though there are slightly higher concentrations in Lorain and Geauga Counties, as shown in **Table 18**.[71]

Table 18: Share of Outdoor Workers by County

County	% of Workforce Employed in Outdoor Occupations
Cuyahoga	17%
Geauga	20%
Lake	21%
Lorain	18%
Medina	19%

Figure 15 shows the total number of outdoor workers by county. Communities need to pay special attention to ensuring the safety of outdoor workers in these areas through interventions such as mandatory rest and water break policies.

Figure 15: Total Number of Outdoor Workers by County



Extreme heat and poor air quality disproportionately affect vulnerable populations, including seniors, young children, and individuals with pre-existing health conditions, exacerbating health inequities across the region. **Table 19** breaks down the distribution of key vulnerable population groups across the MSA. With the increased intensity of these adverse conditions, vulnerable communities will see an increase in adverse conditions that will lead to poor health outcomes. Strategic efforts, including retrofitting older homes, electrification, reducing household energy consumption, can promote climate resiliency and reduce health burdens.

Table 19: Distribution of Climate Vulnerable Population Groups by County [72]

County	Number of Homeless Residents	Children Under Age 18 (% of Population)	% of Schoolchildren Enrolled in Free & Reduced Lunch	Persons Living with Disabilities (% of Population)	% of Adults with Asthma or COPD
Cuyahoga	1,637	250,704 (20.3%)	19.9%	234,589 (21.4%)	20%
Geauga	43	20,903 (21.9%)	19.1%	12,095 (14.3%)	19%
Lake	83	44,014 (19%)	32.3%	37,251 (17.9%)	20.4%
Lorain	178	67,547 (21.2%)	31.4%	56,981 (20.1%)	20.8%
Medina	49	38,854 (21.1%)	26.4%	32,646 (19.9%)	19.9%

Costs of Climate Inaction for Cleveland-Elyria MSA

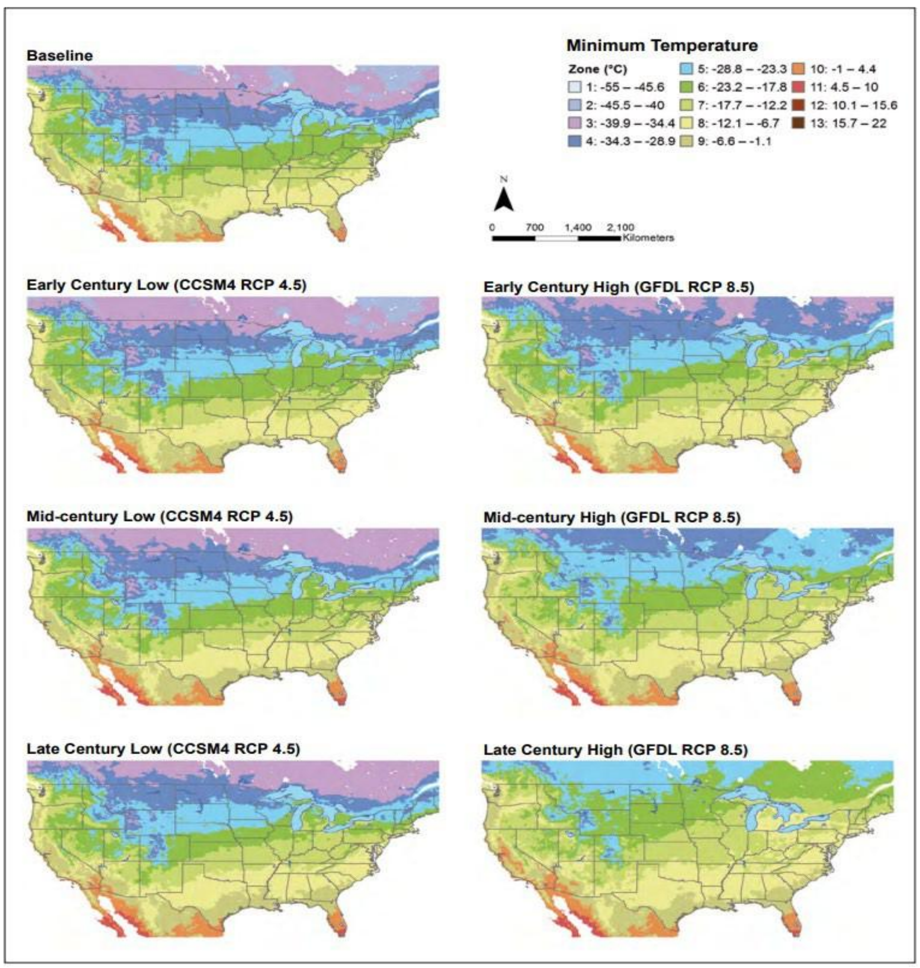
5. Costs of Climate Inaction for Cleveland-Elyria MSA

While decarbonization carries clear financial and social costs, so does inaction. Climate change inaction poses significant, tangible risks to the region. Through collective action to decarbonize the economy, MSA leaders can engage and educate residents, businesses, and organizations on the threat of climate change and necessary actions to face that crisis. If MSA stakeholders fail to act, community will be vulnerable to climate change impacts, but also to lose out on economic and job creation opportunities that will accompany this green transition. Key risks and threats to the MSA's communities, businesses, and residents are outlined below.

5.1. Key Risks & Threats of Inaction

Shifting Climate: The Cleveland-Elyria MSA is warming much faster than the national average, as noted in Section 4.1. By 2080, the climate that has defined this region for centuries will shift fundamentally. In its place, the region will adopt a warmer and more humid climate that more closely resembles Arkansas.[73] Increased humidity will significantly alter spring and summer, affecting agriculture in the region. The U.S. Department of Agriculture (USDA) currently denotes coastal communities in the MSA as plant hardiness level 7a, with the rest of the MSA as 6a or 6b (the lower the number the colder the expected extreme temperature).[74] In a Business as Usual future, in the 2040s the hardiness zones throughout the MSA are expected to be 7a and 7b (see **Figure 16** from Matthews et al, 2018).[75] For grape growers, orchardists, and dairy

Figure 16: Change in Plant Hardiness Zones Under Different Climate Scenarios



farmers, especially in Lake and Geauga Counties, this will profoundly affect harvests, output, and operations.

Heat-Related Deaths: Historically, the Cleveland-Elyria MSA has benefited from temperate summers due to its proximity to Lake Erie. Climate change will increase extreme heat in the region, leading to an increase in the number of heat-related deaths. According to U.S. EPA data, the region's heat-related mortality rate may increase by 675% and 1,700% under low- and high-warming scenarios, respectively. As a result, the MSA could see approximately 60-140 additional heat-related deaths each year.[76]

Lost Opportunities: If regional leaders fail to act decisively, other regions may seize upon some of the opportunities identified in this CCAP. First, given the current demand for clean, firm power (i.e. clean power that is available 24/7/365) for data centers, private vendors may contract directly with Perry Nuclear Power Plant to expand its generation capacity. If this occurs, the region will face a less straightforward path to meet its emissions reduction goals, as this additional clean power capacity would no longer be available to support other decarbonization priorities, such as electrifying buildings and transportation. Second, other Great Lakes cities, such as Chicago and Buffalo, have evaluated investing in offshore wind.[77] While technical challenges have delayed the launch of offshore wind industries in these cities, the growth of floating offshore wind technology may change the calculus in these and other cities. The Great Lakes city that seizes this opportunity first will lead the job growth, training, and business-leadership opportunities in this sector.

Across the globe, the clean energy transition is driving economic growth and job creation. The International Energy Agency (IEA) noted that during 2023, 10% of global GDP growth stemmed from this transition, including 6% of GDP growth in the U.S.[78] This report demonstrates enormous needs for skilled labor and new businesses to transition our buildings, transportation, and electricity infrastructure across the MSA. These opportunities will not materialize in the MSA without action. As other regions accelerate their transition, these opportunities and jobs will gravitate to those regions. It will become harder for the Cleveland-Elyria MSA to attract people and businesses to do this work here.

5.2. Quantifying the Costs of Inaction

One way to estimate the costs of inaction is through the Social Cost of Carbon (SCC). The SCC is a tool to translate the effects of climate change into economic terms to help decision makers better understand the economic impacts of decisions that affect climate pollution.[79] To estimate the social cost of climate inaction, the City of Cleveland and the CRDF team projected cumulative GHG emissions within the MSA from 2023 to 2050 under the Business As Usual (BAU) scenario (see Chapter 6).

Under this BAU scenario, the Cleveland-Elyria MSA would generate approximately 755.3 $MMTCO_2e$ through the middle of the century. In its 2023 technical report on the SCC, U.S. EPA provided a methodology to translate these estimated emissions into estimated costs.[80] Through this approach (using a 2% discount rate), failing to act on climate change would impose approximately $170 billion in total costs upon the MSA through 2050, which is nearly equal to the MSA's 2023 GDP.[81] Annualized costs total more than $6 billion, with a range of approximately $4.2-10.1 billion, depending on the discount rate.[82] **Table 20** breaks down the costs of inaction by county in 2030, 2040, 2050, and across the 2023-2050 period.

Table 20: Social Costs of Climate Inaction for Cleveland-Elyria MSA

County	2030 Estimated Annual Cost ($ Billion)	2040 Estimated Annual Cost ($ Billion)	2050 Estimated Annual Cost ($ Billion)	2023-2050 Estimated Cumulative Costs ($ Billion)
Cuyahoga	$4.1	$3.7	$3.3	$108.1
Geauga	$0.3	$0.3	$0.2	$7.5
Lake	$0.7	$0.7	$0.6	$19.1
Lorain	$0.8	$0.7	$0.6	$20.9
Medina	$0.5	$0.5	$0.4	$14.4
Total MSA	$6.5	$5.9	$5.3	$170

As these numbers demonstrate the economic case for climate action becomes even clearer when one considers the costs to the region from the impacts of a changing climate, such as more extreme weather, reduced worker productivity, and impacts to infrastructure.

Business As Usual (BAU) Projections

6. Business As Usual (BAU) Projections

6.1. BAU Projections Methodologies

The BAU projections for the CCAP build upon the methodology used for the PCAP by NOACA and ICLEI USA. This section provides an updated analysis with the 2022 GHG inventory as the baseline. The following assumptions from the PCAP BAU scenario still apply:

- **Projected Population Growth** - Unlike most regions in the United States, the Cleveland-Elyria MSA has not experienced population growth in recent decades. The regional population is expected to remain constant through 2050.
- **Projected VMT growth** - This analysis assumes that VMT will grow by 0.33% per year, based on data from NOACA (consistent with the PCAP).
- **National Renewable Energy Laboratory (NREL) electricity emissions intensity projections** - This BAU scenario forecasts electricity emissions intensity with NREL's Cambium model.[83] The mid-case for the model projects electricity intensity will decrease by 0.3% annually through 2030. Although electricity is likely to continue to become cleaner from 2030 to 2050, projections are less certain. Therefore, the scenario assumes no additional change in electricity intensity from 2030 to 2050.
- **On-Road Transportation Fuel Efficiency Standards[84] (changes in passenger cars, light truck, medium, and heavy-duty truck[85] fuel economy are expected because of Corporate Average Fuel Economy (CAFE) standards)** - Fuel efficiency standards help project the reduction of emissions intensity for each mile driven by gasoline on-road vehicles. Fuel efficiency standards decrease emissions due to federally mandated improvements in vehicle fuel economy. The CCAP uses the same CAFE projections from the PCAP, which come from the Center for Climate and Energy Solutions (C2ES).[86] These projections assume a 1.8% annual improvement in fuel economy through 2050.
- **Refrigerants** - Federal regulations require an 85% reduction in consumption and production of HFCs by 2036. For 2030, BAU emissions continue due to leakage from existing equipment.[87] Consistent with the PCAP, this analysis assumes the regulation will have minimal impact on 2030 emissions. By 2050 all this equipment will have been replaced with equipment that uses alternative refrigerants. Therefore, this BAU scenario models an 85% reduction in BAU refrigerant emissions between 2030 and 2050.

6.2. BAU Projections Results

The results of this BAU analysis appear in **Figure 17** and **Table 21**. If the Cleveland-Elyria MSA takes no additional action, net GHGs will reach 27.9 and 25.2 $MMTCO_2e$ in 2030 and 2050, respectively. These values represent reductions of 17.4% (2030) and 25.6% (2050) from 2018 levels. While emissions declined under this scenario, it leaves the Cleveland-Elyria MSA far short of its emissions reduction targets.

Figure 17: BAU Scenario GHG Emissions for Cleveland-Elyria MSA, 2018-2050

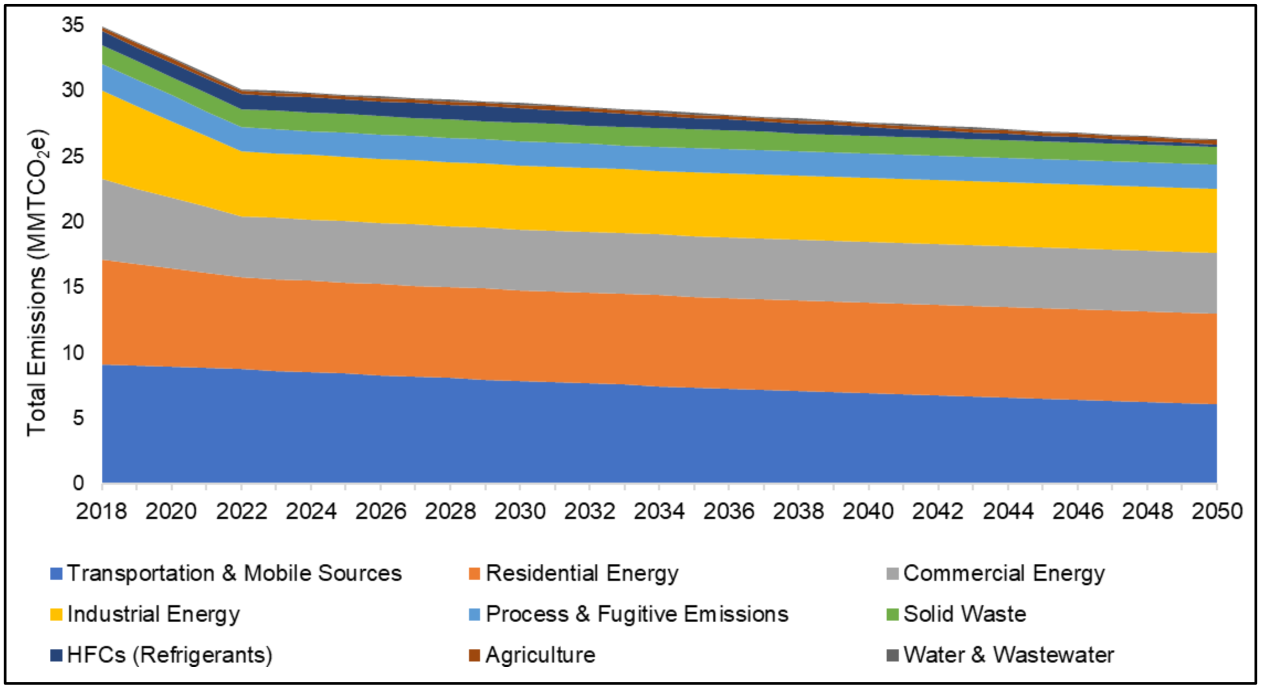
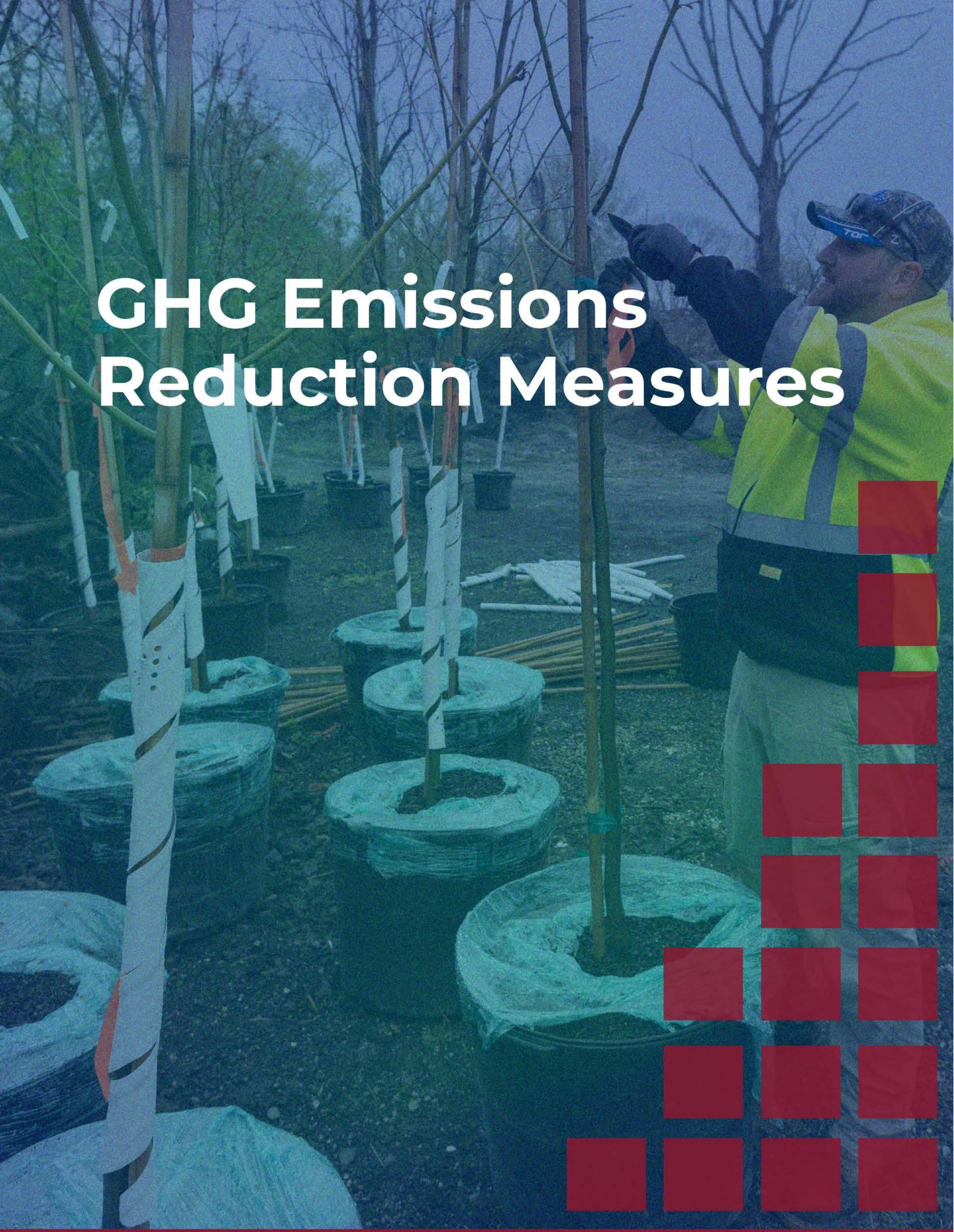


Table 21: BAU Scenario GHG Emissions for Cleveland-Elyria MSA, 2030-2050

Sector	2018 Baseline ($MMTCO_2e$)	2030 BAU ($MMTCO_2e$)	2050 BAU ($MMTCO_2e$)
Residential Energy	7.95	6.93	6.93
Commercial Energy	6.16	4.64	4.64
Industrial Energy	6.79	4.88	4.88
Transportation & Mobile Sources	9.14	7.87	6.08
Process & Fugitive	2.06	1.85	1.85
Solid Waste	1.44	1.40	1.40
HFCs (Refrigerants)	0.12	1.14	0.17
Agriculture	1.01	0.25	0.25
Water & Wastewater	0.30	0.11	0.11
Total Emissions Produced	34.97	29.08	26.31
Emissions Removed	-1.17	-1.17	-1.17
Net Emissions	**33.80**	**27.91**	**25.15**

GHG Emissions Reduction Measures



7. GHG Emissions Reduction Measures

7.1. Summary of Emissions Reduction Measures

As **Figure 18** illustrates, the emissions reduction measures outlined in this plan provide a clear and actionable pathway for the region to approach net zero emissions by 2050. By integrating a broad range of mitigation strategies across all major emission sectors, and outlined in the wedge analysis, this CCAP ensures that the Cleveland-Elyria MSA can systematically address all emissions sources, as required by U.S. EPA guidance.[88] Through 2030, GHG emissions in the MSA will decrease by 45.7%, while emissions fall by a total of 91.5% by 2050. These totals leave the region somewhat short of the targets outlined in Chapter 3. Under this implementation scenario, the Cleveland-Elyria MSA will achieve its 2030 target in 2031 and its 2050 target in 2053. The MSA will need to secure additional external support to accelerate implementation of these measures to meet its target.

Figure 18: Projected GHG Reductions from Measures by Sector, 2025-2050

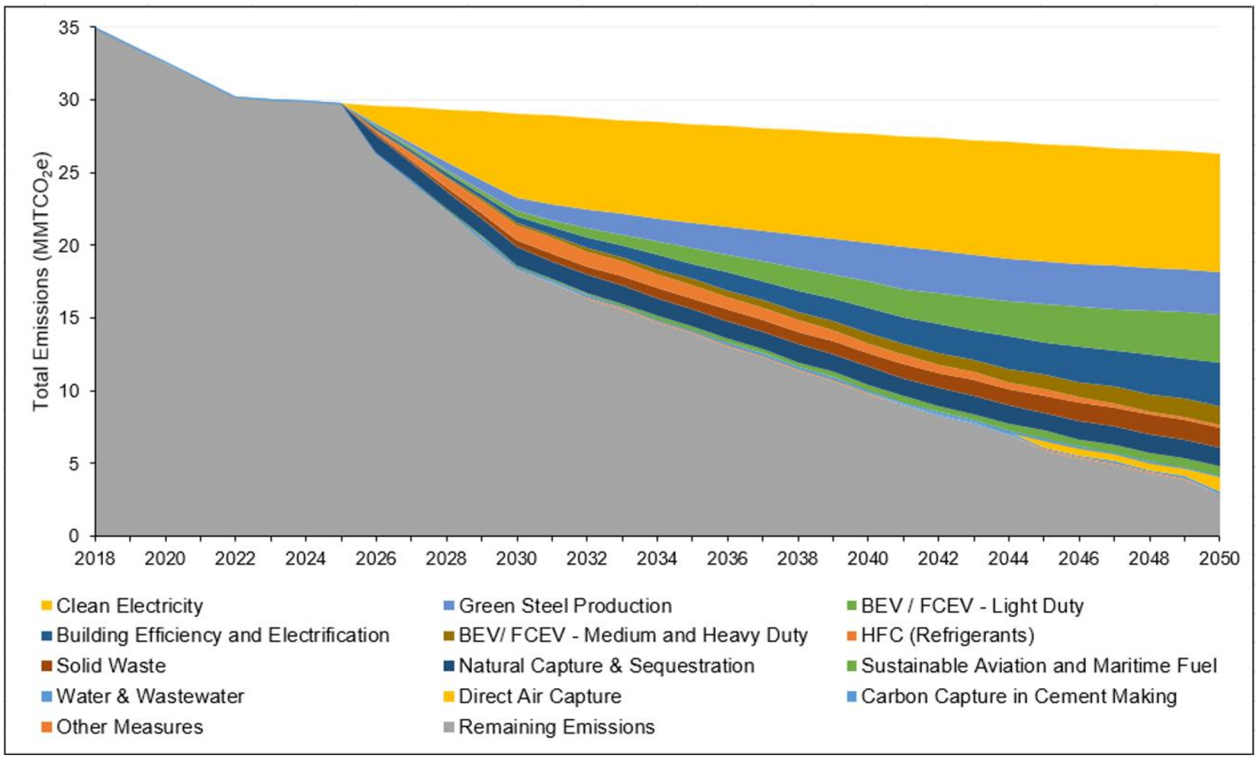


Table 22 breaks down the GHG emissions reductions associated with each measure. It also relates each PCAP priority measure with each CCAP measure. The CRDF team used the PCAP priority measures as the basis for developing this list of CCAP measures; however, the CCAP includes a broader and more detailed collection of measures, which reflects U.S. EPA guidance. This updated list of measures accounts for updated conditions, including data from the 2022 GHG inventory and rising demand for electricity, CCAP measures also go into greater depth to reflect the specific circumstances of the MSA

accounts for updated conditions, including data from the 2022 GHG inventory and rising demand for electricity. CCAP measures also go into greater depth to reflect the specific circumstances of the MSA and to provide concrete details that actors can use to implement measures. Across all measures, the largest savings come from clean electricity, which accounts for 54.4% of total GHG emissions reductions in 2030 and 34.7% in 2050.

Table 22: Emissions Reduction Measures with GHG Reductions, 2030 & 2050

PCAP Measure	CCAP Measure	GHG Reduced by 2030 ($MMTCO_2e$)	GHG Reduced by 2050 ($MMTCO_2e$)
Clean Electricity	Clean Electricity	5.84	8.13
Light-Duty Vehicle Electrification	BEV / FCEV - Light Duty	0.33	3.32
Building Efficiency & Electrification	Building Efficiency and Electrification	0.51	2.97
Green Steel Production	Green Steel Production	0.88	2.94
Solid Waste Diversion	Solid Waste	0.51	1.40
Heavy-Duty Vehicle Electrification	BEV/ FCEV - Medium and Heavy Duty	0.14	1.28
Nature-Based Solutions	Natural Capture & Sequestration	1.20	1.26
N/A	Direct Air Capture	0	1.00
Heavy-Duty Vehicle Electrification	Sustainable Aviation and Maritime Fuel	0.13	0.63
Green Steel Production	Carbon Capture in Cement Making	0	0.18
Refrigerants Capture	HFC	1.03	0.17
Solid Waste Diversion	Water & Wastewater	0.10	0.10
VMT Reduction, Refrigerants Capture	Other Measures	0.08	0.05
Total Emissions Reduction		**10.74 (-45.7%)**	**23.44 (-91.5%)**

Table 23, below, breaks down emissions reductions by sector. The largest share of residual emissions by 2050 occurs from Residential Energy (2.57 $MMTCO_2$), Process and Fugitive Emissions (1 $MMTCO_2$), and Transportation and Mobile Sources (0.8 $MMTCO_2$). Residential Energy accounts for half of residual emissions, demonstrating the scale of the challenge to fully decarbonize the region's housing stock.

Table 23: GHG Reductions from 2018 Baseline by Emissions Sector

Emissions Sector	2018 Emissions ($MMTCO_2e$)	2030 Emissions ($MMTCO_2e$)	2050 Emissions ($MMTCO_2e$)
Residential Energy	7.95	3.87	2.57
Commercial Energy	6.16	3.72	0.50
Industrial Energy	6.79	1.80	0.00
Transportation & Mobile Sources	9.14	7.24	0.80
Process and Fugitive	2.06	1.64	1.00
Solid Waste	1.44	0.90	0.00
Water & Wastewater	0.12	0.01	0.01
Refrigerants (HFCs)	1.01	0.11	0.00
Agriculture	0.30	0.25	0.25
Total Emissions Produced	34.97	19.55	5.13
Reductions and Sequestrations	-1.17	-1.20	-2.26
Net Emissions	**33.80**	**18.35**	**2.87**
Percent Emissions Reduction		**45.7%**	**91.5%**

Table 24 provides a more complete overview of the CCAP measures, including the community types for which they are most applicable, implementation costs, implementation timeframes, whether the actions are low- or no-regret, whether communities have the authority to implement the measures, and whether entities within the MSA have secured funding. No-regret strategies have immediate benefits beyond their decarbonization potential, low costs relative to other solutions, and are unlikely to be made obsolete with technological advancements or vulnerable to extreme weather. Low-regret strategies have immediate benefits, can be implemented in the near term, and represent the best solutions for the moment.

Table 24: Overview of Emissions Reduction Measures

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
BEV adoption of light-duty passenger vehicles by households	BEV / FCEV - Light Duty	All	$$	Medium- to Long-Term	Low-Regret	Yes	Yes
BEV/FCEV adoption in government fleets		All	$$	Short- to Long-Term	Low-Regret	Yes	No
Expand BEV charging infrastructure		All	$$	Short-Term to Medium-Term		Yes	Yes
Expand FCEV fueling infrastructure		All	$$$	Medium- to Long-Term		Yes	No
Reducing Fuel Cost Access to Electric Vehicle Infrastructure		All	$$	Short-Term		Yes	Yes
BEV/FCEV adoption of medium and heavy-duty vehicles by fleets	BEV/ FCEV - Medium and Heavy Duty	All	$$	Short-Term to Medium-Term		Yes	No
Automated Building Systems and Smart Devices	Building Efficiency and Electrification	All	$	Medium- to Long-Term	No-Regret	Yes, for municipal utilities	Yes
Building System Electrification (Deep Retrofit)		Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$$	Medium- to Long-Term	Low-Regret	Yes	Yes
Implementation of the latest state adopted building standards and codes		All	$$	Short- to Long-Term	No-Regret	Yes	Yes
Incentive programs		Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$	Short- to Long-Term		Yes, for municipal utilities	Yes
Increasing Retrofit Envelope Efficiency (Deep retrofit)	Building Efficiency and Electrification	Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$$	Short-Term	Low-Regret	Yes	Yes

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Material Substitution		All	$$$$	Short- to Long-Term		Yes	Yes
Modular and Prefabricated Construction		All	$$$$	Medium- to Long-Term		Yes	Yes
Post combustion carbon capture (cement making)	Carbon Capture in Cement Making	Legacy City, Established City & Town	$$$	Short-Term		Not Currently - would require legislative/regulatory approval	No
Active Energy Adjustment for Grid Support (Demand Response)	Clean Electricity	All	$$$	Medium- to Long-Term		Yes, for municipal utilities	Yes
Brownfields to Brightfields		Legacy City, Established City & Town, Rural Community	$$	Short-Term, Medium-Term		Yes	Yes
Commercial-scale rooftop & parking lot solar		All	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Community enrollment in renewable energy aggregation		All	$	Short-Term	Low-Regret	Yes	N/A
Community-serving microgrid and mini-grid systems.		All	$$	Short-Term, Medium-Term		Yes	Yes
Convert lighting to LEDs		All	$	Short- to Long-Term	Low-Regret	Yes	Yes
District or utility-scale battery storage - Long duration (>10 hours)	Clean Electricity	Legacy City	$$	Long-Term		Yes	Yes
District or utility-scale battery storage - short duration (<4 hours)		Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$	Short- to Long-Term		Yes	No
District thermal energy systems		All	$$$	Short- to Long-Term		Yes	No
Electrification of industrial process heat		All	$$$	Medium- to Long-Term	Low-Regret	Yes	No

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Electrify machine drives in synergy with grid decarbonization		All	$$$	Medium- to Long-Term		Yes	No
Energy audits		All	$	Short-Term	No-Regret	Yes, for property owners and municipal utilities	No
Energy Efficient Equipment		All	$$	Short-Term	Low-Regret	Yes	No
Geothermal electricity generation		Legacy City, Rural Community	$$$	Long-Term		Yes	No
Grid-scale power systems modernization		All	$$$	Short- to Long-Term		Yes	No
Hydrogen as an energy carrier		Legacy City, Established City & Town, First Ring Suburb	$$$	Medium- to Long-Term		Yes, but capacity does not currently exist in MSA	Yes
Intelligent grid management systems		All	$$	Short- to Long-Term		Yes	No
Monitoring Systems		All	$	Short-Term	Low-Regret	Yes	No
New Nuclear at Perry		Outer Ring Suburb	$$$$	Long-Term		Not Currently	No
Offshore wind	Clean Electricity	Legacy City	$$$	Long-Term		Unclear - project approved, but in limbo	No
Opt-in Public Pricing Program for public-sector mercantile customers		All	$	Short-Term, Medium-Term	Low-Regret	Yes	N/A
Physical Purchase Power Agreements (PPAs)		All	$	Short-Term, Medium-Term		Yes	N/A
Residential rooftop solar		All	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Smart Energy Management Systems (Commercial Buildings)		All	$$$	Short- to Long-Term	Low-Regret	Yes	Yes
Utility-scaled solar		All	$$	Short- to Long-Term		Yes	Yes

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Waste heat recovery and utilization systems		All	$$$	Short-Term to Medium-Term		Yes	No
Invest in a regional direct air capture facility for hard to abate sectors	Direct Air Capture	All	$$$$	Long-Term		Not Currently - would require legislative/regulatory approval	No
Carbon capture at Cleveland Works	Green Steel Production	Legacy City, First Ring Suburb, Outer Ring Suburb	$$$$	Medium-Term		Not Currently - would require legislative/regulatory approval	No
Green Steel at Cleveland Works		Legacy City	$$$$	Medium-Term		Yes, but technology is still being developed	No
Switch industrial processes to hydrogen (steel, cement, chemical manufacturing)		Legacy City, Established City & Town	$$$$	Short- to Long-Term		Yes, but contingent on availability of H2	Yes
End of equipment life facilities, drop-off/collection programs for refrigerants	HFCs	All	$$	Short-Term	Low-Regret	Yes	Yes
Use climate friendly refrigerants		All	$$	Medium-Term	Low-Regret	Yes	No
Digital twin to track tree canopy	Natural Capture & Sequestration	Legacy City	$$	Short- to Long-Term		Yes	No
Expand agriculture practices to restore soil health and increase carbon sequestration		Rural Community	$	Short- to Long-Term	Low-Regret	Yes	No
Expand Wetland Restoration Programs		Rural Community	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Land bank set-asides for carbon storage		Legacy City, Rural Community	$	Short-Term	Low-Regret	Yes	No
Model mature tree protection ordinance[89]		All	$	Short- to Long-Term	No-Regret	Yes	Yes

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Reforest agriculture lands no longer in use, increasing the regional tree canopy		Rural Community	$	Short- to Long-Term		Yes	No
Support community greenspace programs for small scale community-based native urban gardens, greenspaces, tree planting		All	$	Short-Term	Low-Regret	Yes	Yes
Support habitat restoration and conservation		Outer Ring Suburb, Rural Community	$	Medium-Term	Low-Regret	Yes	Yes
Tree carbon-capture		Established City & Town, First Ring Suburb	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Automation (non-electricity)	Other Measures	All	$	Short-Term		Yes	No
Install leak detection equipment		All	$	Short-Term	No-Regret	Yes	No
Reduce industrial waste		All	$$$	Short- to Long-Term	No-Regret	Yes	No
Use lower GWP gases for anesthetics		All	$	Short-Term		Yes	No
Expand networks of protected bike lanes, off-street trails, and lane conversions	Other Measures (VMT Reduction)	All	$	Short-Term	No-Regret	Yes	Yes
Increase density and mix of uses around transit stations		Legacy City, First Ring Suburb, Established City & Town	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Install gas capture systems for landfill methane		All	$$	Short-Term	No-Regret	Yes	No
Intercity Passenger Rail and Coordinated Transportation Planning		All	$$$$	Medium-Term		Not Currently - would require approval from State of Ohio	Yes
Add compost bins to public facilities, parks, and sports	Solid Waste	All	$$	Short-Term	Low-Regret	Yes	Yes

CCAP Measure Name	Measure Category	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
stadiums to divert organic waste from land fills							
Restaurant and grocery food waste reduction/composting program		All	$$	Short-Term	Low-Regret	Yes	Yes
Support composting and food waste reduction with organic waste diversion from landfills		All	$$	Short-Term	Low-Regret	Yes	Yes
Advance the use of sustainable aviation fuel at regional airports	Sustainable Aviation and Maritime Fuel	Legacy City, First Ring Suburb, Established City & Town	$$$$	Short- to Long-Term	Low-Regret	Yes, but airlines must agree to purchase SAF	No
Advance the use of sustainable liquid and gaseous fuels at regional maritime ports		Legacy City, Established City & Town	$$$$	Medium- to Long-Term	Low-Regret	Yes	Yes
Invest in high-tech equipment to help detect water leaks in municipal water infrastructure - saving water and energy once repaired	Water & Wastewater	All	$	Short-Term to Medium-Term	Low-Regret	Yes	No
Post incineration scrubbers installed at wastewater treatment facilities with fluidized bed incinerators		All	$$$	Short-Term	Low-Regret	Yes	No

The cornerstone of this CCAP is electrification, which is the largest single lever for decarbonization. Electrification is not only crucial for decarbonizing traditionally high-emitting sectors, such as residential and industrial energy, but is also instrumental for transiting from fossil fuel-based energy to cleaner options. The accelerated deployment of clean energy technologies, such as advanced grid infrastructure, geothermal, wind, and nuclear, will facilitate the replacement of fossil fuels, allowing the electricity sector to reach net zero ahead of the 2050 target. Notably, the reductions achieved through electrification and clean energy integration are expected to surpass the sector-specific targets, providing an essential buffer against uncertainties and helping to accommodate the expected rise in energy demand.

The accelerated integration of clean energy sources constitutes another pillar of this decarbonization strategy. Projected increases in energy demand, largely due to the electrification across transportation, buildings, and industry, will require a substantial and reliable expansion of clean energy generation. Deploying new clean energy generation is essential for facilitating the decarbonization of nearly every source of emissions. On its own, electrification should help to reduce emissions, as electricity is far more efficient than fuel combustion, but ensuring that electricity comes from zero-carbon sources is the only realistic path to net zero.

Despite the depth and breadth of this decarbonization strategy, certain sectors remain difficult to fully decarbonize by 2050. Notably, there remain 2.87 MMTCO2e in residual emissions in 2050. These stem from multiple sectors, including non-electric residential and commercial energy use, transportation, and process & fugitive emissions. These enduring sources reflect a convergence of technological constraints, entrenched legacy infrastructure, and the inherent complexity of processes for which cost-effective zero-emission alternatives are not yet commercially available.

One CCAP measure (Direct Air Capture) has no direct PCAP equivalent. The addition of the DAC measure reflects the fact that certain hard-to-abate sectors (e.g. steel and cement production, heavy-duty trucks) may not achieve complete decarbonization by 2050. The MSA will need to invest in additional carbon removal efforts to offset these remaining emissions, but nature-based solutions (e.g. tree planting) are not sufficient on their own. Net zero will require technological emissions removal, including DAC and geological sequestration of CO_2. Emissions removals, both natural and technological, make up 2.26 $MMTCO_2e$ (9.7%) in total reductions by 2050, almost as much green steel production (2.94 $MMTCO_2e$) or building efficiency and electrification (2.97 $MMTCO_2e$).

Additional technological breakthroughs or the advanced commercialization of existing technologies would also reduce these remaining emissions and help the MSA achieve its targets by 2050.

7.2. Electricity Sector

No other sector possesses as much possibility for meaningful impact on decarbonization in the Cleveland-Elyria MSA. In principle, significant electrification of natural gas applications and process heating, accompanied by grid emissions reduction as the region moves toward net zero electricity, will eliminate climate pollution in this sector. Indeed, this is the work that is before the MSA's communities: to improve the energy efficiency of buildings and operations, reduce waste, electrify, and decarbonize the electricity system.

However, no other sector faces as much uncertainty or uphill resistance as the electricity sector. Electricity demand is set to grow at a rate estimated at 2% each year over the next 25 years.[90] The combination of widespread electrification, demand for green hydrogen and potentially other fuels and chemicals, and changing heating and cooling requirements make the MSA's targets for renewable or net zero energy generation highly uncertain.

7.2.1. MSA Context

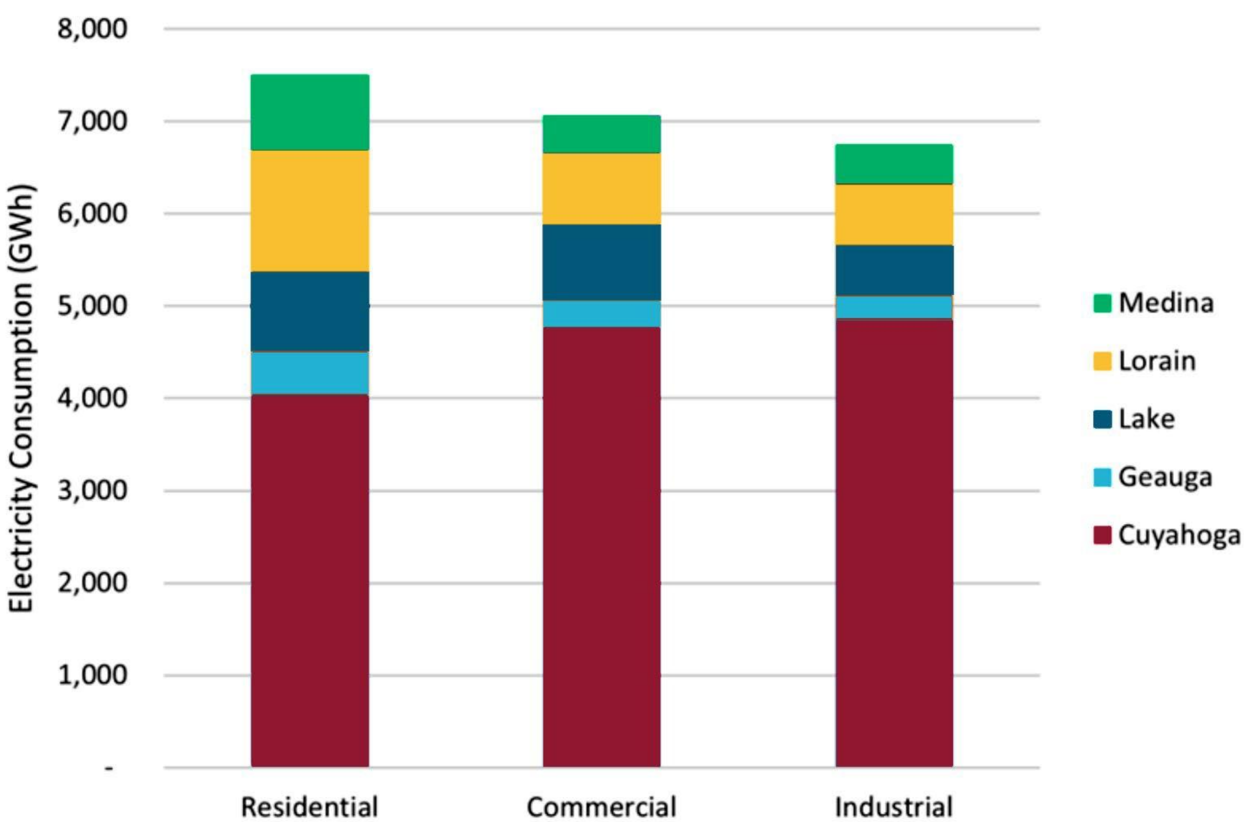
Despite this uncertainty, it is possible to estimate the magnitude of this change. By electrifying transportation and shifting away from fossil fuels in residential, commercial and industrial settings, the MSA will consume approximately 63 terawatt hours (TWh of electricity annually by 2050, though that number may increase even further under a high warming scenario. This number is triple the amount of electricity that the MSA used in 2022 (21.31 TWh. If two-thirds of this electricity demand came from outside the region, the MSA would need to add more than 2,500 megawatts (MW of zero-emissions generating capacity each year over the next 25 years. Assuming capital costs of $2 million per MW, the region must invest more than $200 million annually.[91] The immense growth of electricity needed illuminates the importance of economy- wide energy efficiency measures and grid modernization to lessen and manage such growth.

Nevertheless, communities across the MSA already implement clean energy solutions. The energy aggregators serving the region, the Sustainable Ohio Public Energy Council (SOPEC and the Northeast Ohio Public Energy Council (NOPEC, already provide dozens of communities with 100% renewable energy for residents and small businesses through government aggregation, also known as community choice aggregation (CCA. Solar co-op programs, such as Switch Together, supported by Solar United Neighbors (SUN, enable residents and small businesses across the MSA to add solar to their roofs through group buying discounts.[92] Utility scale solar projects are coming online across the region, including the 4 MW Brooklyn landfill solar farm. In December 2024, Oberlin College began operating a district geothermal system, replacing the legacy fossil-fuel district energy system that served the campus. These projects demonstrate MSA stakeholders are already willing and able to implement clean energy technologies.

New or improved technologies are on the horizon, with significant potential to upend plans for this sector beyond 2035. New nuclear, enhanced geothermal electricity generation, and advances in offshore wind technology can close the gap on the energy transition. Additionally, better, safer, and longer-duration energy storage technologies are expected to be available in the next decade to improve the feasibility of a high-renewable energy portfolio. However, none of these are expected to impact regional near-term targets by 2030.

Electricity: In 2022, the region consumed approximately 21,310 gigawatt hours (GWh) of electricity.[93] **Figure 19** breaks down electricity consumption by sector. Nearly all of the electricity in the MSA moves through the transmission system managed by FirstEnergy, and 87% came from FirstEnergy's distribution utilities, The Illuminating Company (CEI) and Ohio Edison (OE). Smaller public utilities, such as CPP, distributed the balance. For much of the last 25 years, electricity consumption across the region has been relatively flat (growth in some communities, decline in others).

Figure 19: Electricity Consumption by County & Sector (2022)



The MSA's electricity use declined by 7.5% from 2018 to 2022.[94] Without large-scale new demand, utilities met any localized growth through smaller investments in power-quality improvements. Until the last decade, with the arrival of cost-competitive solar, the paradigm for new electricity generation investment has been to build large power plants with hundreds of megawatts of generating capacity, strategically sited around the PJM region.[95] Siting aligned with access to high-voltage transmission lines to serve the multi-state region and access to fuel supplies. Generators have focused efforts on large-scale projects that maximize return on investment. Electricity demand is now expected to grow, so leaders across the MSA will need to intervene or build more natural gas generation.

Natural Gas: Natural gas is a key for heating, cooking, and drying in residential, commercial, and industrial applications in the MSA. In 2022, the region's residential and commercial energy users consumed 117,256,237 MMBtu of natural gas, along with another 1,160,042 MMBtu of Propane and 439,171 MMBtu of Fuel Oil for residences. By 2022, Dominion Energy (now Enbridge) was the largest distributor of natural gas in the region, with smaller but important distributors in Columbia Gas of Ohio, Knox Energy Cooperative, Northeast Ohio Natural Gas, and Northern Industrial Energy Development.[96] Natural gas usage and emissions increased from commercial and industrial sectors from 2018 to 2022 but decreased by 5% in residential energy use over the same period.

7.2.2. Challenges & Barriers to Decarbonizing Electricity Sector

Winter Peak Demand: Winter peak refers to the days during the winter months when extreme cold causes high grid energy demand. Technology combinations such as solar photovoltaic (PV), combined with battery storage, can address the electricity requirements of summer peak. The use of advanced geothermal energy for heating and cooling will address increasing and meaningful portions of the thermal requirements for MSA communities and provide grid relief. However, winter peak events present significant challenges to decarbonization through the lowest cost methods. Winter peak events already produce extremely high electricity demand and high prices, despite the use of natural gas for heating.[97] Additionally, the MSA experiences more than 200 cloudy days per year and an average of 88 cloudy days from December through March.[98] Solar output drops to just one-third of its peak July output in December and January. This drop makes it difficult for solar and storage to provide the MSA's wintertime power demands.[99]

Geography for Energy Storage: Currently, the most efficient long-duration energy storage technology is pumped hydropower, where water is pumped to a reservoir when renewable energy is abundant, and released through a turbine when electricity is required. The MSA only has one remaining dam and reservoir, LaDue on Bridge Creek in Geauga County, which does not generate hydropower. This facility should be evaluated for pumped hydropower. In addition, new long-duration storage technologies, like compressed air and geologic hydrogen storage, may be suitable for parts of Northeast Ohio, but only after 2030 and only if prices fall.

Dependence on Cheap Fossil Fuels: Ohio residents on average pay $0.1651 per kWh, nearly $0.03 and $0.05 less than Michigan and New York, respectively, as a lack of pipeline capacity keeps gas prices down.[100] With costs of new natural gas generation rising and waiting times for new natural gas turbines increasing, the appeal of adding new low-cost solar energy at scale is expected to increase.[101] But given the region's low-cost natural gas, markets alone are unlikely to drive this shift to clean energy.

7.2.3. Local Success Stories & Opportunities

Painesville Brownfield Solar Project: Painesville received $80 million from a $129 CPRG Implementation Grant to transform a 140-acre brownfield into a 35 MW solar array with 10 MW in battery storage.[102] Painesville Municipal Electric will also close its aging coal-fired power plant and upgrade its municipal substation to better serve its customers.[103] This project provides Painesville and its partners, Cuyahoga County and the City of Cleveland, a way to implement a central PCAP emissions reduction measure.

CPRG Solar Grant Press Conference, July 2025. Credit: Cuyahoga County

Perry Nuclear Power Plant: Perry was an early, key tool to help reduce MSA fossil fuel dependence, and it proves the value of nuclear power for the region. Perry is designed to house two 1 GW reactors, but only one reactor exists. The empty pad for the second plant, along with extra capacity across the facility to support additional generation, creates a unique opportunity for the MSA to expand its clean firm generation capacity.

Geothermal & Advanced Geothermal: Much of the MSA has a geology that is favorable for ground-source/geothermal heat pumps to heat and cool residential properties. Oberlin College has also demonstrated that district geothermal solutions can heat and cool across campus-type settings, providing a potential option to replace existing fossil-fuel powered district energy systems. The MSA also sits on the periphery of ideal geologies for advanced geothermal power.[104] The technology has seen tremendous development in recent years, and the MSA could deploy it as a clean, firm energy option in the 2040s.

7.2.4. Electricity Sector Emissions Reduction Measures

The following sections describe a full suite of emissions reduction measures from across the electricity sector which will enable immediate and sustained progress towards MSA near- and long-term GHG reduction targets. These measures largely correspond to the Clean Electricity from the PCAP; however, this section builds upon that initial list of measures to provide a fuller suite of measures that will decarbonize the electricity sector over the long-term.

7.2.4.1. Decarbonize Purchased Electricity

Three measures will help communities in the MSA decarbonize electricity through clean energy purchases. These measures are recommended for immediate implementation. Given that the MSA will need to acquire 40,000,000 MWh from out-of-region, these measures will incentivize the market and regional grids to build more renewable energy.

Government Aggregation: Communities enroll in an aggregation through SOPEC or NOPEC to purchase 100% renewable energy for residential and small business customers in their geography. This offers a low-cost, low-barrier-to-entry solution that also sends strong market signals to build more clean energy generation. This is generally an excellent solution for LIDACs.

Opt-in Public Pricing Programs: Public-sector mercantile customers, including local governments, nonprofit organizations, faith-based entities, and public agencies, can utilize public pricing programs. Within communities served by SOPEC, larger customers not traditionally served by government aggregation plans may opt-in to the 100% renewable energy agreement serving the community. Additionally, any political subdivision in the state of Ohio can join SOPEC to utilize this program including libraries, park districts, transit authorities and sewer districts.[105] This program streamlines and simplifies enrollment, reducing barriers to renewable energy. NOPEC's Preferred Pricing Program similarly offers public-sector entities access to opt-in energy solutions for their municipal loads, including 100% renewable electricity options. As of the end of 2024, the program supported 824 electric accounts in 55 communities, 269 natural gas accounts in 54 communities, and 147 streetlighting accounts in 43 communities.[106]

Power Purchase Agreements (PPAs): These contracts allow larger private sector companies and others not eligible to participate in government plans to acquire 100% clean electricity. While generally not complex arrangements, they do require someone who is knowledgeable about the process. Companies often find that acting in partnership with other organizations allows for better rates. PPAs are not limited to procuring out-of-region electricity; they can also finance the design and construction of on-site renewable generation and energy storage.

Communities/boards governing public utilities should evaluate their governance frameworks and rules to establish clean energy procurement goals. They should also consider moratoriums on new or future contracts with fossil fuel generators.

7.2.4.2. Grid Modernization

Four measures are key for communities to take *in concert with* their electricity utilities to improve power quality, reduce line-losses, mitigate peak loads, and improve resilience. The steps outlined above, as well as additional measures that promote electrification, depend on a robust and energy efficient transmission and distribution grid. Additionally, smart grid systems allow for improved management of distributed energy resources (DERs), such as residential rooftop solar or storage. Without such improvements to the grid, efforts to electrify broad swaths of the MSA will falter as communities deal with outages or low power quality.

Intelligent Grid Management Systems: Distribution system control modernization and management to improve demand response (DR), peak management, engagement of grid-scale storage for frequency regulation and voltage control, and the management of DERs and related generation assets.

This measure enables other important steps to increase the use of renewable energy. First, intelligent systems enable dynamic electricity pricing/time-of-day pricing, which encourages customers to use electricity when it is most abundant and cheapest to produce, typically from solar. By increasing demand for renewable energy and the reward for customers, this mechanism helps support price for abundant solar, while driving electrification.

Second, intelligent grid management systems enable the use of Virtual Power Plants (VPPs). VPPs aggregate distributed energy systems, allowing municipal utilities or grid managers to operate these separate units like a larger system. VPPs could become important electricity management structures in scenarios where we have high community participation in CCAs and a high adoption of rooftop or parking-covered solar within the MSA.

Grid-Scale Power Systems Modernization: Electricity is lost at each stage of the power distribution process. Up to 4% electricity emissions savings across the system are possible, with the greatest savings achieved in rural areas, and during peak.[107] The substation built in Middlefield, Geauga County, in 2012 was designed to perform exactly these functions.

District or Utility-Scale Battery Storage - Short Duration (<4 hours): Battery energy storage systems (BESS) built on existing lithium-ion technologies can provide continuous discharge for up to four hours. Current tariff structures incentivize construction and deployment of such systems to perform peak “shaving” (reduce overall peak load) and frequency regulation. BESS systems also provide electricity during short-term grid outages. These systems are best deployed by district energy, municipal utility, and utility operators. As AI control technology improves, this technology may become suitable for other industrial or commercial applications.

Community Microgrids and Mini-Grids: Microgrids and mini-grid systems provide resilience for critical community infrastructure.[108] By locating such projects to serve critical infrastructure, such as town halls and fire, police and EMS stations, communities can reduce emissions and increase resilience. Larger systems could support additional community buildings and the charging of community service vehicle fleets. The CCAP calls for the development of 50 micro- and mini-grids across the MSA by 2050, resulting in 250 MW of new solar generation.

7.2.4.3. Energy Efficiency

Given overlaps with other sectors, there is only one measure for communities to increase energy efficiency. Energy efficiency measures, such as building weatherization and electrification, rely on proven technologies and are no-regret strategies. Grid-scale power systems modernization, noted above, will be an important measure to improve energy efficiency.

Converting to LEDs: While most cities and communities across the region have transitioned to LED lighting for streets and safety, the division of responsibility for lighting upgrades to park systems, private developers, businesses and political subdivisions has meant that some lights have not yet been addressed. Communities should quickly complete this transition.

7.2.4.4. Solar Energy Generation within the MSA

There are nine key measures for communities to increase the generation of renewable energy within their communities and within the MSA.

Utility-Scale Solar: The MSA can develop 450 MW of utility-scale solar on 1,800 acres of land to support public utilities by 2050.

Brownfields to Brightfields: The MSA can convert 75% (830 acres) of its 1,107 brownfield acres to solar generation and energy storage hubs. At 4.25 acres per MW, there is potential for 195 MW of new brownfield solar in the MSA by 2050.[109]

Residential Rooftop Solar: This measure is a particularly attractive opportunity for residences in outer ring suburbs or rural areas with fewer shading or obstruction considerations. Although these residences may be in communities whose renewable electricity needs are fully met by a government aggregation program, rooftop solar mitigates against the risk of electricity price increases and allows the residents to maximize these low-cost electrons. Through cooperative programs like Switch Together Northeast Ohio, residents can purchase rooftop solar and battery storage collectively, lowering costs and ensuring installation quality. This approach can also help to promote greater community buy-in and control over clean energy, which may strengthen community support for this transition.

There are currently 3,245 residential solar arrays installed across the MSA; in 2024, these panels produced approximately 34,901 MWh of clean electricity.[110] The MSA can reach 1.241 GW of residential rooftop solar by 2050, with adoption rates nearly double in outer-ring suburbs and rural communities.

Commercial-Scale Rooftop & Parking Lot Solar: Businesses and building owners can reduce their energy bills and achieve price certainty by investing in commercial-scale rooftop and parking lot canopy solar arrays. As summer peak energy use continues to increase, these solar installations can critically offset electricity needs when charges are highest and could support participation in DR programs. Parking lot solar, when connected to batteries and EV charging stations, could also be an important source of revenue for property owners. Due to the variability in building size and roof design and configuration, the CCAP conservatively assumes that two-thirds of the MSA's commercial buildings can install solar by 2050, with an average capacity of 17.25 kw per site. Accordingly, this measure can provide 418 MW by 2050.

Large-Scale Solar: Large-scale solar is an important first step to decarbonize the energy sector over the next five years. For every 10 MW of deployed solar, the MSA will generate 12,713 GWh of clean electricity. Furthermore, initial large-scale deployments of solar + battery storage can significantly reduce summer peak demand on the electric grid, which keeps the most-polluting electric generation assets off-line. Communities with abundant, developable rooftop space, surface or garage parking, or brownfields should pursue these opportunities (ex. significant ROI and less community resistance).

Rural communities are key targets for larger-scale solar projects (greater than 10 acres / 2.5 MW), but it is important to engage early and often with the surrounding community and to consider how to integrate agriculture into these projects (e.g., integration with agroforestry, tree screens, etc.). One solution is solar grazing, where vegetation management around solar panels is performed by grazing sheep. Some communities are further experimenting with aspects of agrivoltaics, such as modifying the layout of solar arrays to permit haying operations

Solar Plus Storage: For regions with relatively low solar radiance and high summer-winter variation, such as the Cleveland- Elyria MSA, the sizing and requirements for solar plus storage systems can be considerable for "grid independence." For these reasons, a stand-alone "solar plus storage" solution is not considered except for community microgrids in emergency operations. Solar integrated with other renewables and long-duration energy storage systems (>10 hours, coupled with time-of-day (dynamic) pricing structure and tariffs that drive consumption of electricity when most abundant) provides the foundation for long-term decarbonized energy systems.

It is important to note the requirement to repower solar systems every 25 years, and energy storage systems at 10 years. While this offers advantages, especially as technology improves as anticipated, rebuilding and repowering comes with risk: risk that the operator may not have the capital to make the appropriate upgrades, and risk that supply chains – which will be strained by the enormous demand for green energy – may have long backlogs which result in interrupted power – and the potential for brownouts.

7.2.4.5. District Thermal Energy

District Thermal Energy will primarily be geothermal systems where sufficient land and geology permit. They may also derive their thermal energy from wastewater or industrial/data center cooling water in Legacy or Established Cities or industrial parks. District geothermal solutions are deployed in the region to provide heating and cooling across campus-type settings and provide excellent potential for replacing existing fossil-fuel powered district energy systems. The complexity and high capital cost associated with such systems means that they are best suited to district energy or municipal utility type organizations that have the expertise to operate such systems. Such projects are highly efficient, keep electricity loads low, and have a strong return on investment when well-operated and maintained.

Wastewater or other waste heat district systems require the convenient geography of being closely sited with buildings which can use the rejected heat. With the anticipated rush to build new Data Centers, and their significant cooling and heat-rejection requirements, industrial developments or micro-grid type projects could be sited and designed with such technologies in mind.

The emissions savings from these technologies are difficult to estimate, as the productivity of each “district” depends on a multitude of site-specific factors. The added efficiency that these new systems create can exceed 30% and generate important cost savings for the operator. The MSA should complete 12 such systems completed across the MSA by 2050, with an estimated cumulative 36 Million MMBTu natural gas replaced each year, resulting in 23.3 $MMTCO_2e$ avoided.

7.2.4.6. Long Duration Energy Storage

Cheap and effective, long-duration renewable energy storage greatly improves the utility of renewable energy. New battery chemistries, including flow batteries, may provide the scale and safety required but are still more than five years away from large commercial deployments. Still, with the excellent opportunity for renewable energy from offshore wind after 2035, long-duration energy storage systems paired with such a solution may be able to meet more of the region’s needs than one can contemplate today. Long duration storage achieves the greatest emissions reductions when paired with abundant renewable energy; when carefully managed by a district or utility-scale operator; and at peak demand when replacing electricity that would otherwise come from the most polluting generation sources.

7.2.4.7. Hydrogen as an Energy Carrier

Hydrogen used as a chemical form of energy storage is technically feasible today, but significant technology and materials improvements are needed for it to become cost competitive as energy storage. It is far more likely that, by 2050, hydrogen will displace fossil fuels in those industrial processes not suited to electrification, and in some heavy transportation use. Most hydrogen consumed within the MSA will be produced outside of the MSA. Nevertheless, by 2040, there should be enough renewable energy capacity within the MSA to power a 50 metric ton per day (MT/day) hydrogen electrolysis production facility. This facility would require 100 MW of renewable or zero-emissions energy. The MSA could expand that by adding 100 MT/day facility by 2045, should there be enough new nuclear or geothermal electricity available to support this production.

Behind the Meter Hydrogen Production

The hydrogen industry has been experimenting for decades with solid oxide electrolyzers (SOEs) to make hydrogen and syngas. These systems can operate with great efficiency when combined with facilities producing large quantities of waste heat (over 500°C). Access to the waste heat is necessary to reach the efficiency and price targets for such systems. The expansion of new nuclear offers a unique opportunity to co-locate a hydrogen production facility on-site or immediately adjacent to take waste heat from the electricity operations and use it for SOEs.

7.2.4.8. Nuclear Energy

Key community and business leaders may enter negotiations with the Perry Nuclear Power Plant to support the construction and completion of new reactors at the site. These discussions should include support for further extension to the lifetime of Perry Reactor 1. Nuclear power remains the best technology available today (expected to be available to 2040) to meet electricity demand for winter months and especially winter peak events. Nuclear offers the additional benefit of the highest capacity factor of any generation source, at 92.5%[111] Adding 2 GW of nuclear generation in 2046-2047 will reduce GHGs by 5.98 $MMTCO_2e$ annually, for a total of 26.9 $MMTCO_2e$ from 2046 to 2050.

Perry Nuclear Power Plant. Source: Wikimedia Foundation.

U.S. EIA estimates that advanced nuclear power costs around $88 per MWh. This cost is well above other energy sources, including solar, wind, and natural gas, but current tax credits can lower that total.[112] As the region experiences a significant increase in demand for electricity, this price will likely become more competitive. Expanding generation at Perry will likely require stakeholders in the MSA to sign offtake agreements, rather than make capital investments. This option would free up resources to invest in other emissions reduction measures.

Perry has the capacity to expand. Its empty pad may be the single most significant decarbonization asset in the MSA, as this additional room greatly reduces the cost of siting and permitting new nuclear. The potential to expand nuclear generation could power additional community and economic growth in the MSA, as residents and businesses who seek clean, firm power will recognize the value of this facility. [113] New nuclear capacity could also enable the development of green hydrogen production in the region, which will be key to decarbonizing heavy industry, including steelmaking. Further support for nuclear energy should warrant close monitoring. It may become a point of advocacy if the Cleveland-Elyria MSA communities choose to support this technology and strategy.

Nevertheless, recent history demonstrates the logistical and political challenges of bringing new nuclear generation online. Research shows that nuclear projects often experience significant cost and time overruns.[114] Standardized facilities (e.g. AP1000) can help address this challenge, but expanding generation at Perry will still require extensive community engagement and buy-in.

7.2.4.9. Offshore Wind Energy

Studies from Project Icebreaker, the proposed pilot project for six (6) offshore wind turbines in Lake Erie, indicated a very favorable wind environment for large-scale electricity generation.[115] Despite earlier opposition, the available wind resource is too attractive to forego, and this remains an important post-2030 development option. Offshore wind remains an attractive option for countries with relatively low seasonal solar output, and it has the potential to spark a local wind power industry. Nevertheless, offshore wind faces significant opposition and regulatory hurdles at the federal level, including the repeal of tax credits and withdrawal of permits.[116]

7.2.4.10. Geothermal Electricity Generation

Companies such as Fervo Energy will combine advances in drilling techniques with advanced heat-exchange technology to generate electricity at utility-scale plants.[117] MSA communities find themselves on the periphery of ideal geologies for advanced geothermal solutions.[118] MSA could take advantage of and deploy such a solution in the 2040s. The technology is promising and can provide baseload generation at cost-competitive rates.[119]

Other renewable energy technologies include Onshore Wind and Biofuels. Onshore wind is not ideally suited given the density of the MSA, the State of Ohio’s restrictive wind setback rules, and the relatively poor quality of onshore wind in the region Biofuels grown from regional agricultural products are potentially attractive, but slow market-uptake has diminished interest. In the mid-2010s, significant work was done on the opportunity to transition marginal agricultural land into grassy perennial crops, especially miscanthus, for biofuel production.[120] However, significant demand remains for renewable natural gas, especially for industrial purposes, or for use in Sustainable Aviation Fuel.

Non-renewable energy technologies include adopting combined heat and power (CHP systems with natural gas electricity generation, and carbon capture for generation facilities. Traditional natural gas power plants waste 30-50% of their energy input as heat. Waste heat capture to use as additional power generation or district heating could improve plant efficiency by 10-20%.[121] While neither is a recommended course of action, given the number of natural gas plants in Ohio, these may be necessary solutions to evaluate in future years.

7.2.5. Electricity Sector Benefits & Co-Benefits

GHG Emissions Savings: Electricity demand is expected to triple within the MSA by 2050. Approximately 66% of this electricity will be purchased from renewable or zero-emissions sources from outside of the MSA through government aggregation or PPAs. Grid modernization measures and LED replacements will improve efficiency, optimize use of electricity when most plentiful, and reduce losses. The remaining third of electricity, approximately 22 TWh per year, should come from clean energy generation within the MSA. This strategy results in cumulative emissions reductions of 75.5 $MMTCO_2e$ avoided in this sector by 2050. More aggressive timelines and capital investment would result in more emissions being avoided.

Electrification and clean energy will create jobs and improve air quality. The air quality co-benefits and reduction of critical air pollutants are addressed in the subsequent sections. With an estimated 58 residences per workday adding solar panels, the job and business creation from this sector will be substantial.

LIDAC Benefits and Co-Benefits: Of the GHG reduction measures, government aggregation is the easiest to execute, has the lowest barrier to entry, and is accessible to LIDACs. Investments in intelligent grid management systems and grid-scale power systems modernization will improve power quality, reduce power outages, and enhance the ability to support increased electricity demand due to electrification for LIDACs. While all solar projects have the potential to indirectly benefit LIDACs through the aggregate reduction in emissions from fossil fuel combustion, the “brownfields to brightfields” strategy has the additional benefit of improved land use for under-utilized or degraded sites, many of which are in or adjacent to LIDACs. The addition of large solar power plants to these sites can result in local tax benefits (i.e., increased revenue for these communities. LIDAC communities would also benefit from community ownership of clean energy assets, through programs such as Switch Together or Cleveland Owns (for City of Cleveland residents.[122]

Costs to the MSA: Costs for each GHG reduction measure show high degrees of uncertainty for technologies to be introduced after 2035. The adoption and deployment of rooftop and utility-scale solar are more certain. An average 3.45 kw rooftop solar system costs about $9,000 per residence, and utility scale solar has an estimated all-in cost of $2 million per MW.

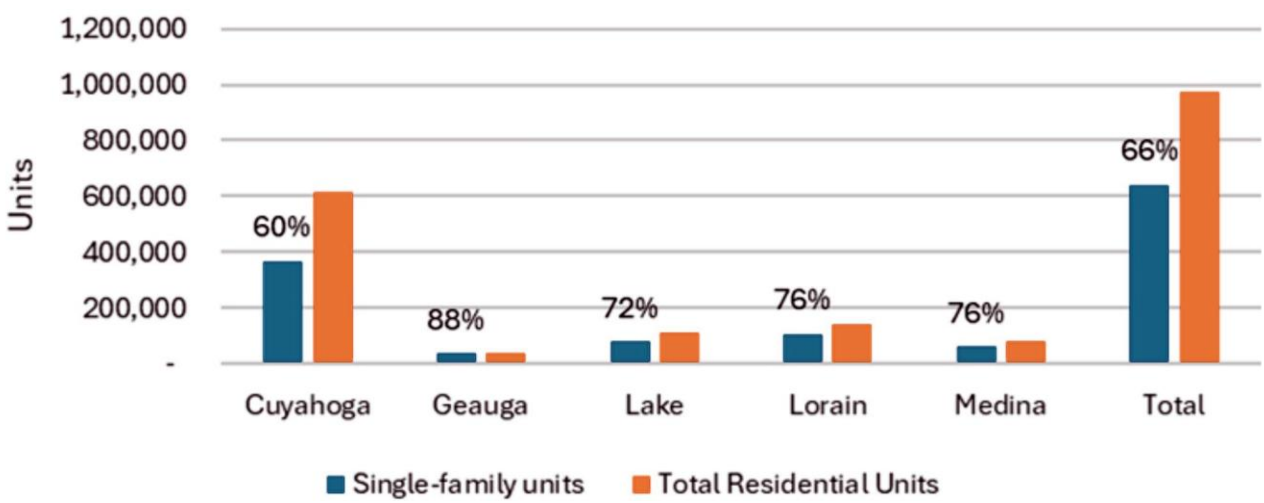
7.3. Residential & Commercial Energy Sector

The building sector (Commercial and Residential Energy) accounts for approximately 39% of GHGs in the MSA. While most buildings in the region are residential, commercial properties account for roughly equivalent energy consumption. Decarbonization will require minimized energy use and reduced embodied energy of construction materials. This is possible through improved building envelope materials and enhanced equipment performance with recycled, locally sourced, and low-embodied energy materials. The lowered energy consumption can be further offset through renewable energy sources, either at home, community, or utility levels.

7.3.1. MSA Context

The building sector is pivotal in the path toward regional decarbonization in the Cleveland-Elyria MSA. Residential buildings account for a substantial share of GHGs due to aging infrastructure, outdated heating systems, and historically inefficient construction practices. As such, the building sector offers a significant challenge and an unprecedented opportunity for reduced emissions, advanced fairness, and economic development. The Cleveland-Elyria MSA's diverse housing stock (**Figure 20**) presents a unique challenge in decarbonizing the building sector. The region must address both the existing housing, which often suffers from poor energy performance, and newer developments that must meet more stringent environmental standards. Fairness considerations are central to the strategy to ensure the benefits of decarbonization reach all communities, particularly those historically underserved.

Figure 20: Residential Building Stock by County in the Cleveland-Elyria MSA



There are approximately 975,000 residential units in the MSA. The MSA has an older housing stock; most residential units are over 50 years old, as shown in **Figure 21**.[123] This aged stock presents a significant challenge for energy efficiency, as many of these homes were constructed under outdated building codes that lacked modern insulation standards and energy performance requirements. Over time, the deterioration of building envelopes further reduces energy efficiency. As a result, these older units require substantially higher heating loads, greater energy use, increased utility costs, and more GHG emissions. Regional decarbonization and energy fairness requires communities to address the inefficiencies of this legacy housing stock.

Figure 21: Age of Residential Buildings in the Cleveland-Elyria MSA

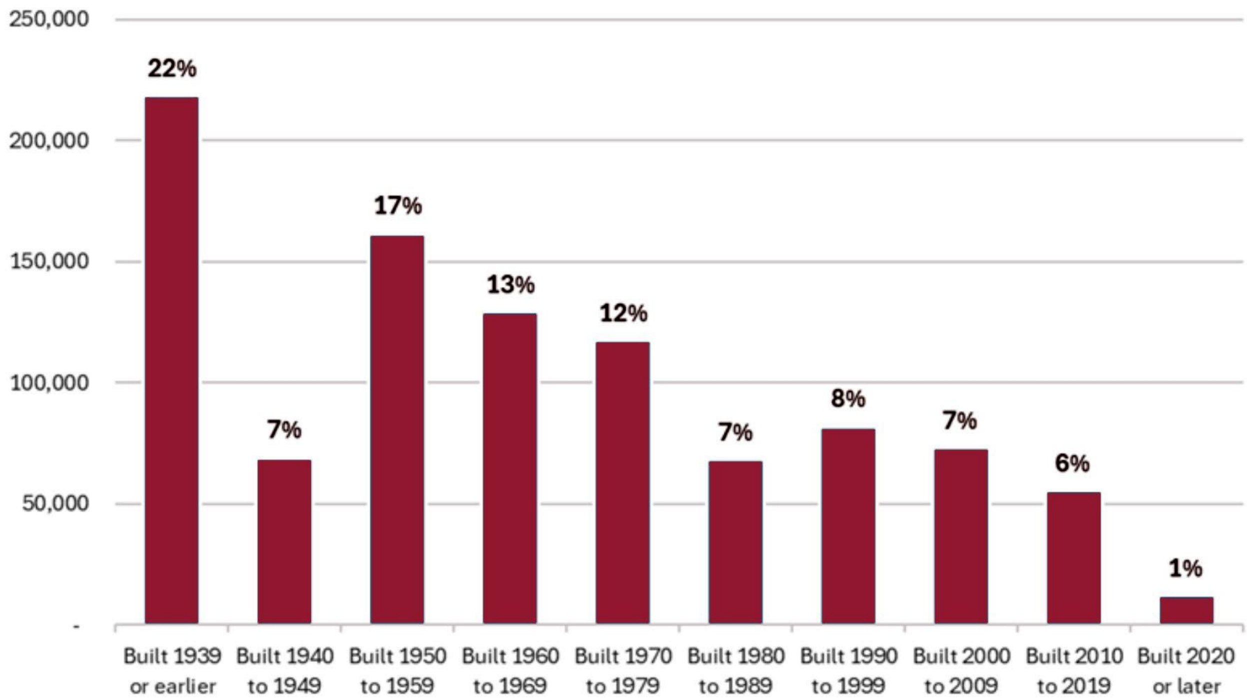
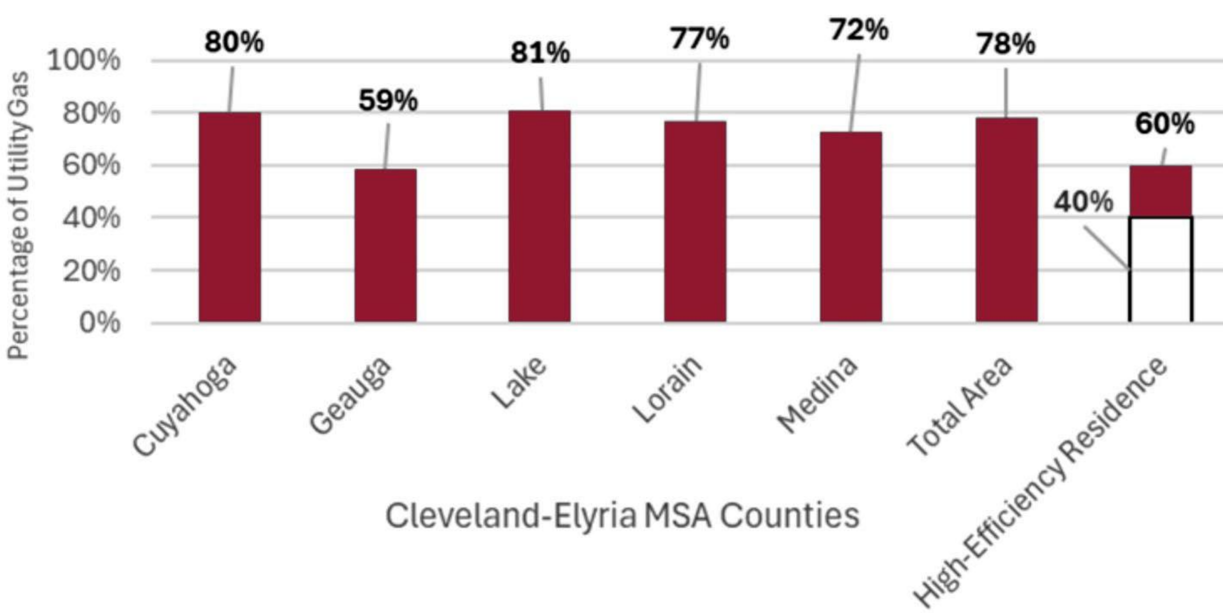


Figure 22 illustrates the MSA's reliance on natural gas for heating. Nearly eight in ten homes use gas, with a range from 59% in Geauga County to 81% in Lake County.[124] This high consumption, particularly in older housing stock, underscores the urgent need for decarbonization efforts, as such homes typically exhibit lower energy efficiency due to factors like inadequate insulation and outdated heating systems.

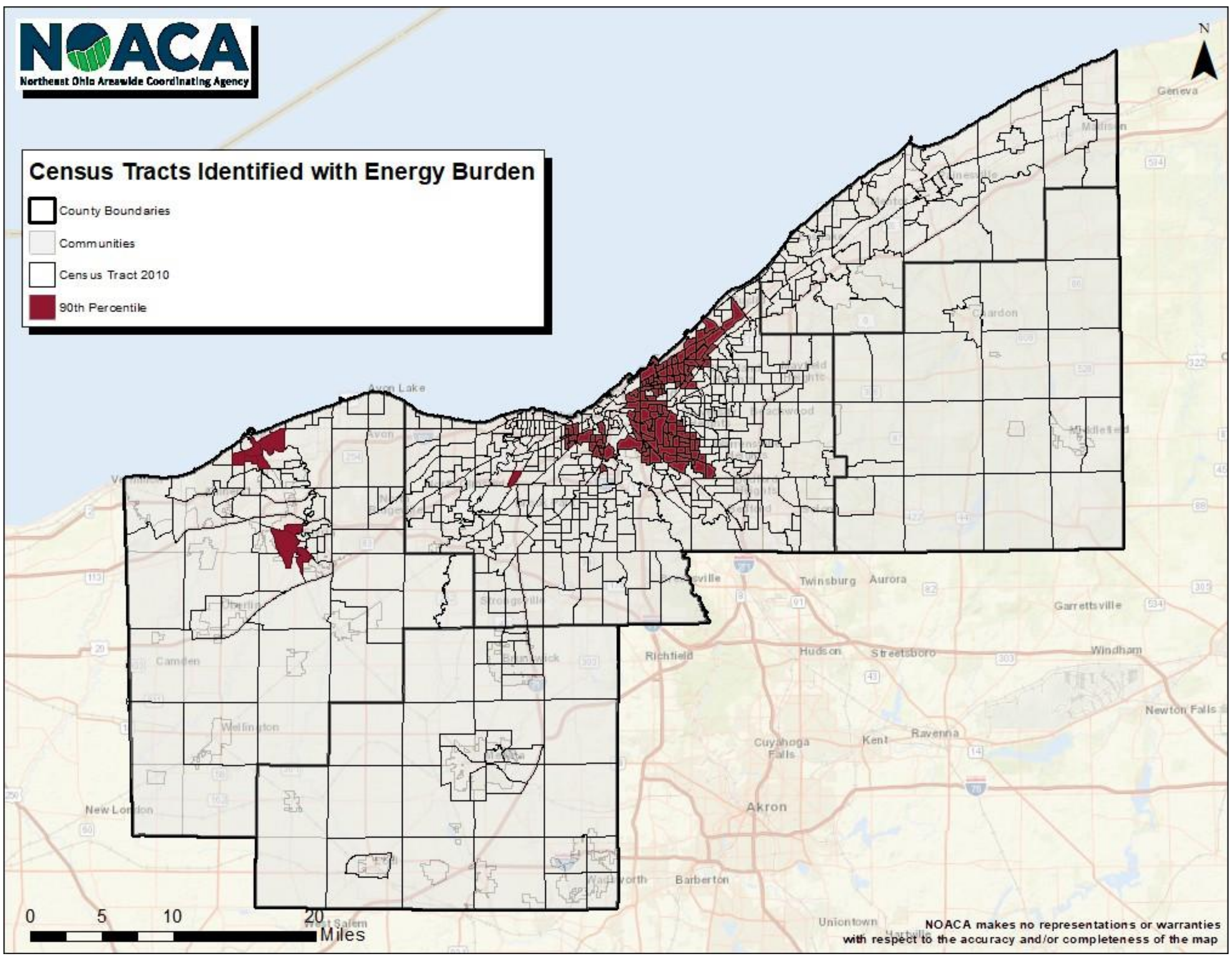
Figure 22: Share of Natural Gas for Residential Heating by County



The MSA's commercial and residential buildings produced a total of 11.7 $MMTCO_2e$ during 2022. Residential buildings accounted for most of these emissions, primarily from natural gas (4.1 $MMTCO_2e$) and electricity (2.8 $MMTCO_2e$). Commercial buildings contributed approximately 4.7 $MMTCO_2e$, with emissions split between electricity (2.6 $MMTCO_2e$) and natural gas (2.1 $MMTCO_2e$).

High energy burdens disproportionately affect low-income households, especially in older neighborhoods where inefficient housing increases utility costs. **Figure 23** displays household energy burden across the Cleveland-Elyria MSA. A fair energy transition means weatherization, renewable energy access, and financing mechanisms that address historical underinvestment in marginalized neighborhoods.

Figure 23: Census Tracts at or Above 90th Percentile for Household Energy Burden



There exists a diverse coalition of public, private, and nonprofit stakeholders that will play a role in decarbonizing buildings within the MSA. These include, but are not limited to, county governments, municipalities, NOACA, the Cleveland 2030 District, the Northeast Ohio U.S. Green Building Council (NEOGBC), Evergreen Cooperatives and Ohio Cooperative Solar, private sector builders and developers, and institutions of higher learning.

7.3.2. Challenges & Barriers to Decarbonize Buildings

Decarbonization in the Cleveland-Elyria MSA's building sector faces several challenges, including the aging of the building stock, socio-economic disparities, fragmented governance, and limited financial mechanisms.

Aging and Inefficient Building Stock: A significant number of buildings in the area predate modern energy codes. Many buildings lack sufficient insulation, have single-pane window glazing, and rely on inefficient HVAC systems. Detached single-family homes are less energy-efficient on a per-unit or per-square-foot basis than multi-family housing.

Economic Constraints: Low-income residents often experience high energy burdens; their utility bills consume a disproportionate share of their income. Many homeowners and landlords lack access to the capital or financing necessary for upgrades like heat pumps or insulation retrofits. Rental properties suffer from the "split incentive" problem. This issue occurs when landlords make decisions about capital improvements, but tenants must pay the utility bills. As a result, landlords have little financial motivation to invest in energy-saving upgrades, as they do not directly benefit from the lower energy costs. Commercial building decarbonization requires significant upfront investment, which slows implementation. Commercial building decarbonization also requires specialized design expertise to abide by building codes, fire safety, and structural issues.

Policy, Regulatory, and Institutional Barriers: The region lacks strong building performance standards, such as mandatory energy benchmarking or efficiency requirements. Building code enforcement is fragmented, with different rules and enforcement practices across municipalities, making it hard to create a unified regional approach. Additionally, existing utility regulations and pricing structures often do not support electrification or local renewable energy generation, and programs like retail net metering face increased challenges in Ohio.[125]

Technical and Workforce Limitations: There are significant technical and workforce challenges to scale energy efficiency and electrification in the MSA.[126] There is a shortage of locally trained professionals for energy audits, heat pump installations, and weatherization work. Additionally, the lack of high-resolution building energy data makes it difficult to prioritize buildings and develop targeted retrofit strategies. This hinders planning and decision-making.

Fairness for Underserved Communities: Historically redlined neighborhoods and former industrial areas often contain the least efficient housing stock, yet these communities face systemic barriers to investment, including limited access to financing and structural neglect.[127] Moreover, residents in older, poorly maintained buildings are more likely to suffer from inadequate ventilation and heating, which can worsen respiratory conditions and increase vulnerability to extreme temperatures.[128]

Electric Grid Readiness: The MSA's electric grid is not ready to support full building electrification. Much of the infrastructure is outdated and built for lower, gas-based energy use. Substations and transformers often lack sufficient capacity, particularly in rural areas of Geauga and Medina Counties, and reliability issues persist in urban neighborhoods. The region also faces barriers to integrate rooftop solar and other renewables due to weak interconnection policies. Without major investment in grid upgrades, smart meters, storage, and demand management, full electrification could strain the system and deepen energy inequities.

Vacant Buildings: There are approximately 9,200 vacant buildings in the City of Cleveland, with thousands more across the rest of the MSA.[129] These buildings challenge regional decarbonization efforts.

Embodied carbon is already "invested" in vacant buildings. Roughly 20-40 tons of carbon is stored in existing building materials, and this “disappears” when buildings are demolished. For comparison, rehabilitation retains 60-80% of this embodied carbon while it generates only 8-18 tons of GHGs, creating a compelling case for rehabilitation over demolition.[130] Concentrated demolition patterns in distressed neighborhoods, such as those in Cleveland and East Cleveland, could reduce per-building emissions by 20-30% through equipment efficiency and coordinated transportation. Scattered rural demolitions in Lake, Geauga, and Medina Counties might generate 40-80% higher emissions due to longer travel distances.

Rehabilitation consistently outperforms demolition across all geographic contexts in the MSA, typically 60-75% lower carbon emissions per building. Yet, while rehabilitation produces lower carbon emissions than demolition, the cost to retrofit older vacant homes to achieve carbon neutrality far exceeds the building's market value, particularly in LIDACs. Communities must evaluate decarbonization goals in the context of economic realities and community fairness.

7.3.3. Local Success Stories & Opportunities for Buildings

EcoVillage Cleveland: Cleveland’s EcoVillage near Lorain Avenue and West 65th Street showcases the city’s commitment to combine environmental and economic sustainability through energy-efficient homes, shared green spaces, community gardens, and green transportation, all of which reduce utility costs and support affordability. Community organizations and local partners enhance social development through education and programs that promote recycling, gardening, and pollution prevention.

The project exemplifies neighborhood-scale sustainability through a comprehensive suite of decarbonization strategies embedded in its residential and community design. The development emphasizes energy-efficient building envelopes with superior insulation, meticulous air sealing, and high-performance windows to minimize thermal loads. Passive design measures, such as optimal building orientation and integration of natural ventilation, further reduce energy demand. Residents benefit from efficient mechanical systems, including high-efficiency HVAC units and energy-saving appliances. Many homes either include solar PV systems or are designed to be easily upgraded for renewable energy integration. The selection of sustainable materials supports lower lifecycle emissions. Additionally, water conservation is prioritized through rainwater harvesting and drought-tolerant landscaping. A pedestrian-friendly layout and shared amenities encourage walking and cycling; they reduce transportation-related emissions and foster a sense of community.[131]

Adam Joseph Lewis Center for Environmental Studies, Oberlin College: This building serves as an exemplary model of a high-performance educational facility designed to reduce GHGs. It is passive solar design through strategic building orientation and thoughtful daylighting, which maximizes natural light and solar heat gain in winter while mitigating summer overheating. The building envelope features advanced insulation and high-performance glazing, complemented by rigorous air sealing to minimize heat loss. Natural ventilation is utilized whenever climatic conditions permit, reducing dependence on mechanical cooling systems. Additionally, the facility utilizes geothermal heating and cooling through ground-source heat pumps, which offers an efficient and renewable approach to year-round temperature regulation. The combination of all these strategies makes the Center a pioneering demonstration of sustainable architecture in higher education.[132]

Source: Oberlin College

7.3.4. Residential & Commercial Energy Emissions Reduction Measures

Deep decarbonization of the Cleveland-Elyria MSA's residential and commercial buildings requires a coordinated strategy of electrification, high-performance construction, low-carbon materials, equitable retrofits, and grid-interactive technologies. Key actions include replacement of fossil fuel systems with heat pumps; addition of on-site solar and net zero designs; and supportive policies for future battery storage. New buildings should exceed baseline codes with LEED, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 189.1, and passive design. Developers can cut embodied carbon with mass timber, low-carbon concrete, and prefabricated systems, supported by life cycle analysis (LCA) and procurement incentives. Fairness-focused retrofits, community solar, robust data, and workforce training help reduce energy burdens. Finally, smart controls and grid integration make buildings flexible, reliable assets that facilitate renewable energy use. Together, these measures create a low-carbon, resilient, and fair built environment.

The following sections describe a full suite of emissions reduction measures from across the residential and commercial energy sectors which will enable the Cleveland-Elyria MSA to make immediate and sustained progress towards its near- and long-term GHG reduction targets. These measures largely correspond to the Building Efficiency and Electrification measure from the PCAP; however, this section builds upon that initial list of priority measures to provide a fuller suite of measures to decarbonize this sector over the long-term.

7.3.4.1. Energy Efficiency Retrofits in Existing Buildings

To improve the energy performance of existing buildings, start with improved building envelopes and mechanical and control systems. Upgraded insulation significantly reduces thermal energy losses. Additionally, advanced framing techniques help minimize thermal bridging and improve overall wall performance.

Tighter building envelopes through comprehensive air sealing and blower-door testing further reduces heat loss due to infiltration. One of the most significant energy conservation strategies is to replace existing windows with low-emissivity (Low-E), double-pane models; this improves thermal efficiency by reducing conductive heat transfer. Mechanical system upgrades, including the installation of Energy Recovery Ventilators (ERVs) and Dedicated Outdoor Air Systems (DOAS) (ground-coupled heat pumps in appropriate areas) enhance ventilation effectiveness while conserving energy.[133] Finally, occupant-responsive controls, such as daylight and motion sensors, ensure that lighting systems operate only when needed. This reduces unnecessary energy consumption. Together, these measures create a more efficient, comfortable, and sustainable indoor environment.

Urban Heat Island (UHI) mitigation strategies, such as cool roofs, reflective pavements, increased tree canopy, and green infrastructure, can reduce urban temperatures and decreasing demand for air conditioning. While the direct impact on GHG emissions is relatively modest (around 3-6%), these measures improve comfort, reduce peak energy demand, and enhance urban resilience.

The MSA's commercial buildings have a variety of styles and configurations, and appropriate retrofits will depend on when and where they were built. Examples of commercial buildings in the region and recommended decarbonization approaches include:

- **Mid-century office buildings:** These typically have single-glazed windows, minimal insulation, and masonry construction. Rainscreen overcladding with strategic window replacement would increase building performance; up to 60% reduction in facade-related energy losses.
- **Aging medical facilities:** These buildings are typically constructed of concrete panel construction, with thermal bridges and air leakage issues. EIFS or prefabricated panel systems could reduce thermal losses by approximately 50% while maintaining operations.
- **Suburban office parks:** These facilities often have tinted glazing, spandrel panels, and outdated curtain walls. Window wall replacement systems with optimized glazing could reduce energy use by 40% with improved daylighting. Additional benefits include reduced glare and an enhanced working environment.
- **Downtown high-rise buildings:** These buildings have curtain wall systems with poor thermal performance. Opaque areas can be overclad with high-performance systems, resulting in a 30-40% reduction in energy use and reduced maintenance costs.

Policies to support energy efficiency retrofits include:

- Regional weatherization programs for pre-1975 homes;
- Advocacy for enhanced statewide energy code enforcement to require minimum retrofit standards during renovations;

- Adhere to the PCAP schedule milestones to retrofit existing buildings with energy-efficient technologies to ensure timely and effective implementation;
- Integrate mapping and planning efforts to prioritize vulnerable and underserved communities; and
- Integrate UHI strategies in climate adaptation and zoning plans.

7.3.4.2. Electrification & Renewable Energy Integration

Technologies and Strategies include:

- **Air Source and Ground Source Heat Pumps:** Replace gas furnaces and boilers with electric heat pumps that use ambient air or geothermal heat;
- **On-Site Solar PV Systems:** Promote the installation of monocrystalline PV panels to offset electricity consumption;
- **Net Zero Home Design:** Combine energy-efficient architecture and rooftop solar to achieve net zero annual energy use;
- **Battery Storage:** Encouraging battery systems as backup and load-shifting solutions.

Policies to support electrification and renewable energy integration include:

- Restoration and expansion of incentive programs for residential solar and electrification (e.g., tax credits, rebates, partnerships with utilities);
- Zoning code revisions to allow easier installation of PV panels and ground loops for geothermal systems;
- Prefabricated net zero energy manufactured homes in the region;
- Expand role and reach of the Growth Opportunity Partners, the regional green bank, in collaboration with the private sector to finance green projects in the region;
- Encourage and support the establishment of construction materials recycling facilities in the region; and
- Propose voluntary green building code that promotes electrification over new gas hookups.

7.3.4.3. High-Performance New Construction

For the building sector to approach carbon neutrality, the Cleveland-Elyria MSA region must encourage and incentivize developers to adopt higher standards such as ASHRAE 189.1, LEED, EnergyStar, or EPA GreenCheck. These standards adopt holistic approaches to promote energy efficiency, reduce energy losses, and enhance comfort.

Technologies and Strategies include:

- Better enforcement of building energy codes;
- Adopt efficient HVAC design and proper ventilation schemes;
- Adopt Energy Efficient lighting systems and Passive Design Features, such as optimal solar orientation, thermal massing, shading devices, and daylighting controls; and
- Implement Smart Energy Management Systems, such as digital monitoring of HVAC, lighting, and plug loads for continuous efficiency.

Policies to support high-performance new construction include:

- Offer density bonuses or streamline permits for developers to build high-performance homes;
- Propose legislation that requires all municipal construction projects to adopt LEED or equivalent high-performance building standards; align these requirements with the Ohio Facilities Construction Commission (OFCC) mandate for public school buildings.

7.3.4.4. Low-Embodied Carbon Construction

Reduced embodied energy in buildings is critical to achieve deep decarbonization targets, and several strategies and technologies can support this effort. One key approach is material substitution, which involves using lower-emission alternatives such as mass timber, low-carbon concrete, sustainably sourced timber, and recycled steel. In addition, integrating LCA tools into the design process enables architects and engineers to assess the GWP of different materials and make informed decisions that prioritize environmental performance. Another effective strategy is the adoption of modular and prefabricated construction techniques, which streamline manufacturing and on-site assembly processes. These methods significantly reduce material waste and embodied energy by allowing for more precise fabrication and less on-site disturbance.

Policies to support low-embodied carbon construction include:

- Encourage procurement standards that require environmental product declarations (EPDs);
- Provide incentives to use low-embodied energy and regional (within a 500-mile radius) materials in building construction;
- Pilot low-embodied-energy construction targets for public housing and demonstration projects;
- Integration of embodied carbon metrics in regional carbon accounting frameworks.

7.3.4.5. Grid-Interactive Buildings and Demand Flexibility

Smart technologies in buildings are crucial to enhance energy efficiency and grid reliability. Smart thermostats and load controllers help reduce peak demand through energy use adjustments during times of high grid stress and can be programmed to align consumption with the availability of renewable energy sources. Adopting smart sensors in both residential and commercial buildings supports real-time monitoring and more responsive energy management. Additionally, Building-Grid Integration (BGI) enables structures to function as flexible loads through automated energy response systems. This allows buildings to adjust their energy consumption dynamically based on grid conditions. Together, these technologies improve energy performance, reduce emissions, and enhance the resilience of the electricity system.

Policies to support grid-interactive buildings and demand flexibility include:

- Collaborate with utilities to pilot demand response programs for residential buildings, and advocate for the State of Ohio policies that enable investor-owned utilities to participate in and scale such programs actively;
- Include Time-of-Use (TOU) pricing structures that reward off-peak energy use for higher-income users;

- Support smart meter rollouts and access to real-time energy data; and
- Promote the development and deployment of VPPs to aggregate distributed energy resources, enhance grid reliability, facilitate renewable energy integration, and reduce emissions.

7.3.4.6. Options to Fund Residential & Commercial Energy Measures

There are many creative strategies to fund GHG reduction measures in this sector that reduce the MSA's dependence on unpredictable funding sources from the state and federal government. These include:

- Establish public-private partnerships with local utilities, significant institutions, and philanthropic investors in the regions;
- Expand the issuance of green bonds;
- Continue to seek grants benefiting underserved communities in the region;
- Integrate clean energy investment with the Cleveland-Elyria MSA regional and county action plans;
- Collaborate with NOACA and regional development boards;
- Frame green projects as economic development initiatives;
- Create demonstration funding for rooftop solar at schools and workforce development initiatives; and
- Expand the availability and uptake of Property Assessed Clean Energy (PACE) and Commercial PACE (C-PACE) financing.

7.3.5. Benefits & Co-Benefits from Residential & Commercial Energy Measures

Table 25 outlines the costs and benefits, including for LIDAC communities, from emissions reduction measures in the Residential and Commercial Energy sector.

Table 25: Cost-Benefit Analysis of Residential & Commercial Energy Sector Measures

Measure Category	Measure Name	Cost Benefit	LIDAC Benefits
Energy Efficient Retrofits	Retrofit homes 30 years or older (3 scenarios)	The total cost of the full implementation of the measure by 2050 is $8.55 billion, with total annual savings of $161.5 million, resulting in a payback period of approximately 53 years.	Reduced energy bills and improved Comfort and health in residential spaces. Increased cost of renting or owning a home and gentrification
	Smart Building System Electrification	The total cost of the measure by 2050 is $5.95 billion, while the annual savings are $262 million, resulting in a payback period of approximately 23 years.	Reduced energy bills and improved Comfort and health in residential spaces. Increased cost of renting or owning a home and gentrification

	Incentive programs	It is estimated that the total cost of the measure by 2050 will be $6 billion, while annual savings are expected to be $0.7-1.1 billion, resulting in a payback period of approximately 7 years.	Reduce Energy Burden, improve indoor air quality, thermal comfort, and health.
High-Performance New Construction	Enhance Energy Efficiency in New Homes and Commercial Buildings through Codes and Incentives.	The total cost of the measure (implementation and enforcement) by 2050 is $273.55 million, with annual savings of $55 million and a 5-year Payback period.	This could result in improved housing stock for the future, along with better occupant comfort and health. However, it is essential to consider that if such constructions occur in LIDAC areas, these buildings may increase property values and rents, leading to gentrification.
	Smart Energy Management Systems	The total cost of the full deployment across 70 million ft² of new buildings and 85 million ft² of renovated commercial buildings by 2050 is $391.75 million, and the expected annual savings are $6.3 million, with a 62-year Payback period.	Improved energy savings, indoor air quality, and health. Increase resilience by reducing reliance on the grid. However, this can be expensive and may increase the risk of gentrification. The digital divide and lack of tech literacy may be potential barriers.
Low-Embodied Carbon Construction	Material Substitution	The total cost of the program's full deployment by 2050 is $1.25 billion, and the expected annual savings, predominantly driven by the SCC, are $4.2 million	Improved housing quality, lower utility costs, reduced reliance on international trade uncertainties for construction, improved health for building occupants, and enhanced building resilience.
	Modular and Prefabricated Construction	The total cost of the full application of the program by 2050 is $87.75 billion, and the expected annual savings (operational and SCC) are $745,560.	Improved home affordability, improved indoor health and comfort, lower utility bills, local jobs, and climate resilience
Grid-Interactive Buildings & Demand Flexibility	Automated Smart Controls & Local Flexible Loading	The total cost of the full application of the program by 2050 is $70.1 million, and the expected annual savings (operational and SCC) are $15.75 million, with a Payback period of about 5 years	Lower energy burden for vulnerable households, reduce blackouts in disadvantaged areas, and explore potential opportunities for local job creation in smart technology equipment and systems installations, as well as energy reduction programs administration and management.
	Grid-Coordinated Demand Response & Load Shaping	The cumulative upfront cost of the program by 2050 is $1.1 billion, and the expected annual savings (operational and SCC) are $40 million, with a Payback period of about 28 years.	Improved grid quality due to the reduction of demand from industrial facilities
Sector Total		**Total Cost: $122.8 billion**	**Total Savings: $90 billion**

7.3.6. Workforce Analysis for Residential & Commercial Energy Measures

Decarbonized Cleveland-Elyria MSA residential and commercial building sectors will influence local labor markets and employment opportunities significantly.

Employment Opportunities & Job Creation: The Political Economy Research Institute (PERI) at the University of Massachusetts-Amherst projects that a clean energy investment program in Ohio, valued at $21 billion annually over a decade, could generate around 165,000 jobs per year.[134] This encompasses investments in energy efficiency, renewable energy, and related infrastructure. Additionally, investments in manufacturing, infrastructure, land restoration, and agriculture could create another 70,000 jobs annually across the state. Decarbonization strategies, such as building energy retrofitting, heat pump and DOAS unit installations, solar PV system integrations, and advanced building analytics, will require a diverse and specialized workforce. These include HVAC technicians, electricians, insulation specialists, energy auditors, and building inspectors.

Addressing Workforce Shortages: The ongoing shortage of skilled labor in the building and energy sectors is a concern. Mechanical technician and construction worker jobs are forecast to grow at 4% annually from 2022 to 2032, which illustrates the need for targeted workforce expansion initiatives in the MSA.[135] Emphasis on energy-efficient building practices and new construction techniques presents an opportunity to attract, educate, and retain skilled labor through dedicated workforce development programs.

Building Code Officials: There is a critical need to expand the workforce of building code officials in line with increased demand for energy code compliance. The National Institute of Building Sciences and the International Code Council anticipate a retirement rate of approximately 80% of existing code officials by 2030, which suggests a pressing need to proactively establish robust educational and inspection programs to train the next generation of building inspectors and code officials.[136]

Fair Workforce Development: Decarbonization efforts must engage historically underrepresented communities to ensure equitable access to training and job opportunities. This inclusion must address the socio-economic disparities to ensure broader economic participation in the transition to a sustainable energy economy. Leveraged partnerships with CBOs, religious groups, and local trade associations can enhance the inclusiveness of workforce programs, thus promoting economic fairness across the five-county region.

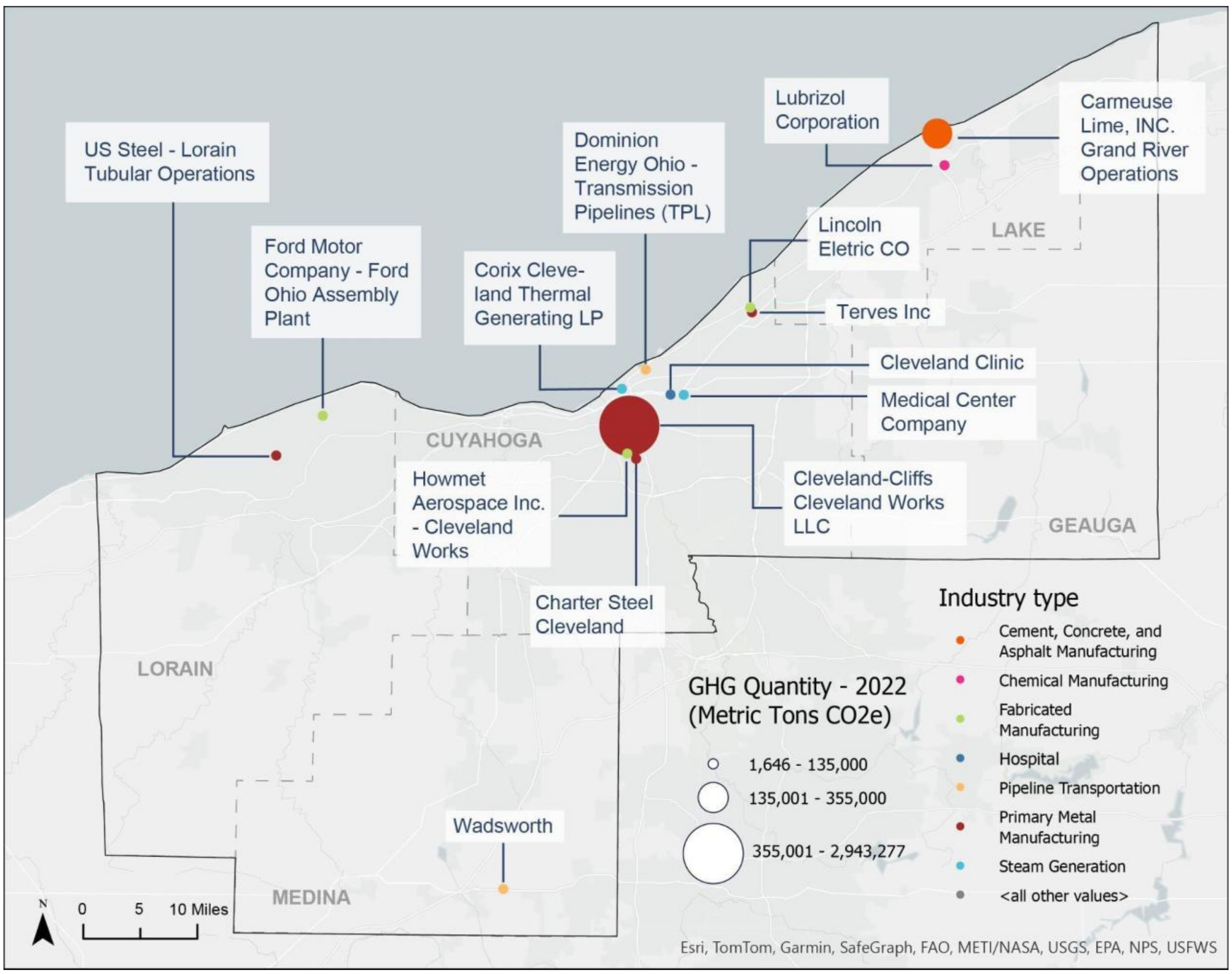
7.4. Industrial Energy & IPPU Sector

Industrial sector decarbonization is crucial to reach net zero goals across the Cleveland-Elyria MSA; industry accounted for 22% of emissions. This section describes actionable strategies and policies to decarbonize industry, focusing on eight of the most common point source emitters across the five counties: primary metal manufacturing; cement, concrete, and asphalt manufacturing; fabricated manufacturing; pipeline transportation; chemical and plastics manufacturing; steam generation; hospitals; and paper manufacturing.

7.4.1. MSA Context

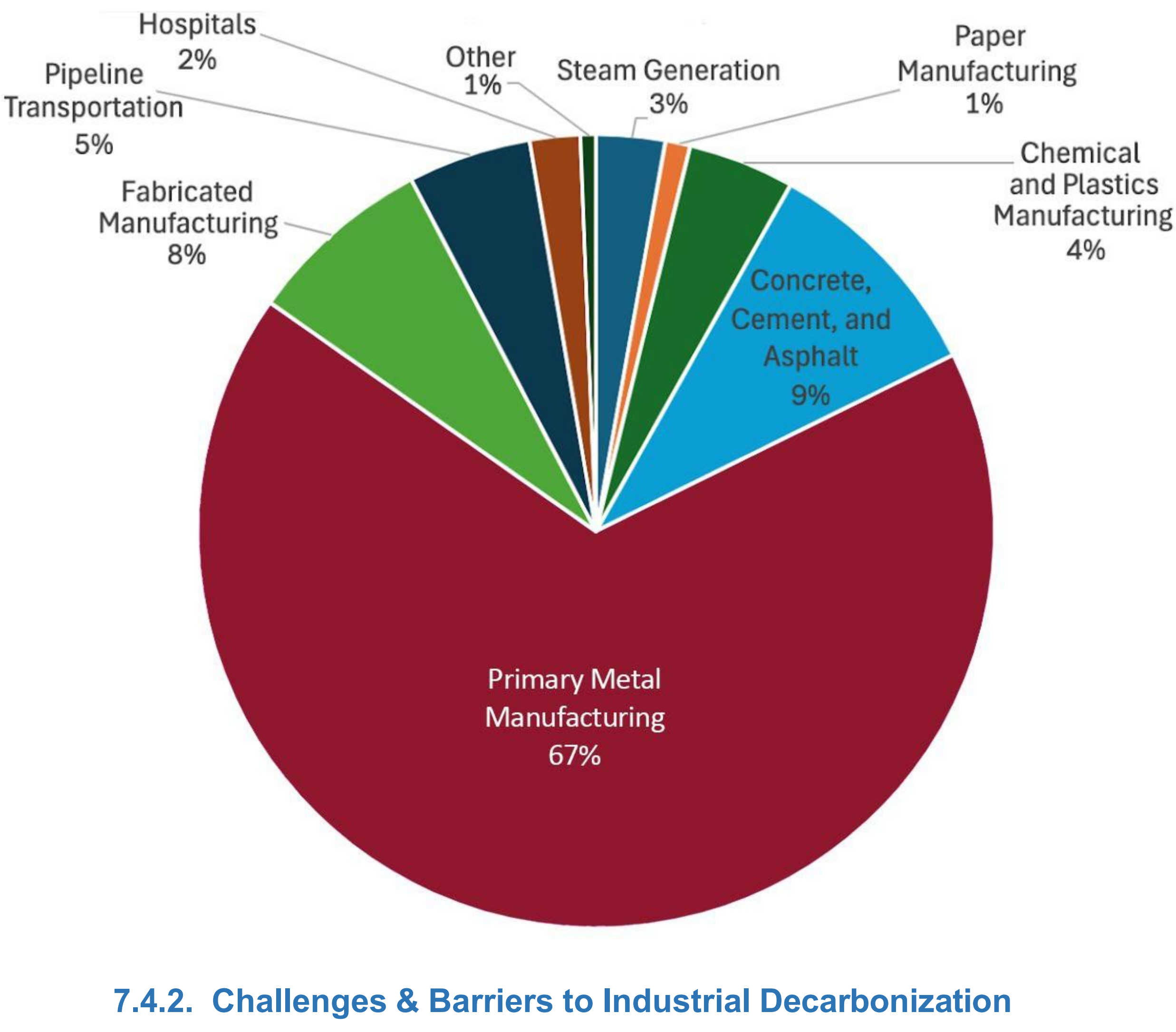
While industrial emissions are found in each of the five counties, the distribution of those emissions is not equal for each county. During 2022, Cuyahoga County produced more than five times as much industrial emissions than the other counties, as it is home to a larger number of manufacturers and the largest single-point emitter in the region, Cleveland-Cliffs' Cleveland Works integrated steel facility. Nevertheless, Geauga, Lake, Lorain, and Medina Counties also have many industries with opportunities for decarbonization. **Figure 24**, below, shows the large industrial emitters in the region. The color represents different types of industries, and the size of the circle shows the relative quantity of emissions.[137]

Figure 24: Large Industrial Emitters in the Cleveland-Elyria MSA



Industrial processes vary widely, and decarbonization solutions for one specific industry may not be feasible or relevant to other subsectors. This section focuses on eight major subsectors in the region, based on the North American Industry Classification System (NAICS) codes for each facility.[138] **Figure 25** breaks down emissions by industrial subsector in the MSA. Nearly 98% of Cuyahoga County's industrial emissions stem from primary metal manufacturing or the iron and steel industry. In Geauga County, 71% of the industrial emissions are due to fabricated manufacturing from furniture. Another large source (29%) in Geauga County is from cement, concrete, and asphalt manufacturing. In Lake County, cement, concrete, and asphalt manufacturing produced 71% of the industrial emissions, with chemicals and plastics manufacturing and paper product manufacturing making up 19% and 10%, respectively.[139] Lorain County has four large subsectors: fabricated manufacturing (38%); primary metal manufacturing (28%); chemical and plastics manufacturing (28%); and cement, concrete, and asphalt manufacturing (6%). Industrial emissions in Medina County are primarily due to pipeline transportation emissions (80%) and cement, concrete, and asphalt manufacturing (18%).

Figure 25: Industrial Emissions by Subsector for Cleveland-Elyria MSA



7.4.2. Challenges & Barriers to Industrial Decarbonization

There are many challenges to decarbonize industry in the Cleveland-Elyria MSA, particularly the fact that there is no single strategy or technology that can decarbonize all industries. Emissions sources within industry vary by subsector and even by facility, and tailored solutions to each case are necessary. Another key challenge stems from financing, as it can be difficult to justify capital-intensive investments in industries with small profit margins. In addition, many technologies (e.g., carbon capture and green steel making technologies) are not yet demonstrated at a commercial scale, which increases investment risk.

Additionally, many strategies depend on infrastructure that is not within the control of industry. To electrify heating processes, there must be a resilient, robust, and decarbonized electric grid. Switching feedstocks or incentivizing carbon capture requires reliable transportation and storage infrastructure for hydrogen and CO_2. Finally, the largest barrier in the Cleveland-Elyria MSA is the need to balance between regulation and local economy maintenance.

This section highlights existing opportunities to aid industries in decarbonization as well as recommend a benchmarking strategy that encourages local industries to decarbonize.

7.4.3. Local Success Stories & Opportunities

Many industries in the Cleveland-Elyria MSA have taken real measures towards real sustainability. Cleveland-Cliffs' oily wastewater treatment plant employs chemical flocculation (CF) electrocoagulation (EC) to treat oily wastewater before release. These processes lead to significant cost savings and environmental benefits.[140] During 2023, the emissions intensity of steel produced at Cleveland-Cliffs' integrated steel mills declined to 1.54 $MTCO_2e$ per ton, a 15% reduction from 2020. This number is 28% lower than the industry-wide average.[141] Lubrizol, headquartered in Wickliffe, is committed to sustainable chemical engineering. The company has reduced its scope 1 and 2 GHG emissions by 21%, has 13 sites that use 100% zero-carbon electricity, and reduced its waste-to-landfill by 25%.[142]

Cleveland Works Facility, Source: City of Cleveland

The Cleveland Clinic, the MSA's largest employer, has also invested in sustainability. Their "green the OR" program targets two key areas: energy efficiency and waste reduction/recycling. The Clinic has established HVAC setbacks that decrease air exchange rates; converted to LED lighting; and manually powered down resources at day's end to save over $100 million since 2010. The hospital also minimizes single-use tools; uses rigid sterilization containers; and pilots new technology to capture and reuse waste anesthetic gases.[143] These local success stories demonstrate that industries in the MSA are willing to invest in decarbonization strategies, especially when they promote energy and material savings for that industry.

7.4.4. Industrial Energy & IPPU Sector Emissions Reduction Measures

The following sections describe a full suite of emissions reduction measures from across the Industrial Energy and IPPU sectors, which will help the Cleveland-Elyria MSA make immediate and sustained progress towards its near- and long-term GHG reduction targets. These measures largely correspond to the Green Steel Production measure from the PCAP; however, this section builds upon that priority measure with a fuller suite of measures to decarbonize this sector over the long-term. While steel production is the largest source of GHGs from industry in the MSA, it only accounts for two-thirds of emissions; thus, the CCAP adds measures that also address the remaining one-third of industrial GHGs.

There are seven overarching strategies to decarbonize industry, based in part on the US Department of Energy (U.S. DOE) *Industrial Decarbonization Roadmap*.[144] Those strategies are: Energy Efficiency, Process and Material Efficiency, Electrification, Alternative Fuels, Renewable Energy, Carbon Capture Utilization and Sequestration (CCUS), and New Industry Support. DAC is another regional solution that can supplement these measures.[145]

7.4.4.1. Industrial Energy Efficiency

Beyond the decarbonization benefits from lower use of energy resources, energy efficiency saves money and reduces waste. While the specific application of energy efficiency methods varies across subsectors, measures include energy audits, energy monitoring systems, energy efficient equipment, automated processes, combined heat and power systems, and waste heat or steam recovery systems.

Energy Audits: Energy audits establish a baseline for energy consumption at a facility and can identify specific opportunities for energy savings in existing equipment, updates, or processes. DOE-funded Industrial Assessment Centers (IACs) provide free energy audits and energy efficiency implementation grants for small- to medium-sized manufacturers.[146] Energy audits with ENERGY STAR or the U.S. DOE's IACs can provide more specific opportunities for energy efficiency for the specific facility, including scalability of equipment to process sizes. Occasionally, facilities are over-engineered for their process. Properly sized motors, pumps, fans, etc. for the process could save up to 15% electricity.[147] The U.S. DOE also offers its Better Plants Program to connect industrial partners with national lab-based technical account managers. These managers can consult on energy efficiency and decarbonization strategies that best fit the facility.[148]

Monitoring Systems: Energy monitoring systems in industrial buildings or along key processes give real-time updates of energy usage and identify energy waste and process inefficiencies, leading to energy savings of 5-10%.[149] Digital monitoring equipment gives real-time updates on energy consumption and can give insights into setting optimization. This allows for better energy management, consistency in operations, and reduced energy consumption.[150]

Energy Efficient Equipment: Energy efficient equipment depends on the industry subsector (see Appendix A) but on average, energy efficient motors, pumps, variable drive motors, high-efficiency coolers and furnaces and other high-efficiency equipment can reduce energy consumption by 10-20%.[151]

Automation: Automatic shutoffs when equipment isn't in use reduces the emissions from idle power consumption and can reduce electricity consumption 5-10%.[152] Smart scheduling to schedule on/off times for areas of the hospital or other facilities that operate constantly, that don't need to be operating continuously (e.g., operating rooms) reduce energy consumption by turning off HVAC, lighting, and non-critical equipment during low-demand times. This can save up to 10% power consumption.[153]

CHP: CHP systems could be implemented in facilities that need process heating as well as electricity generation onsite. They can capture and utilize waste heat; reduce the need for fuels for heating processes; and improve energy utilization 20-30%.[154] This would reduce emissions from electricity usage in powering pumps, motors, and other electric equipment.

Waste Heat Recovery Systems: According to the Department of Energy, 20-50% of industrial energy input is lost in the form of waste heat.[155] Adding heat recovery systems to processes could recover significant amounts of waste heat that can be fed back into the original heating system; used in other processes; or used in combined heat and power systems.[156] Waste heat recovery systems that recover heat from furnaces, machining, and forging processes can be reused for preheating metal or elsewhere throughout the facility. This reduces energy demand by 20-30%.[157] Alternatively, heating process line (gas lines, steam pipes, and molten metal transport systems) insulation prevents heat loss in the first place and improves heating efficiency, leading to 5-10% reductions in heating energy.[158]

7.4.4.2. Process & Material Efficiency

Process and material efficiency reduce the consumption of energy and raw materials through improved process design and best practices. Solutions vary by subsector, but there are four techniques that may be relevant to each industry: shortened supply chains, recycled materials, automation, and process changes.

Shorten Supply Chains: Industries should look for opportunities to source materials locally and shorten supply chains. This would also minimize supply chain disruptions and could reduce industrial transport emissions by 60%.[159]

Recycle Materials: Instead of designing items for single use in cradle-to-grave frameworks, all industries should consider potential secondary use for their products. Industries should design them in a cradle-to-cradle framework (i.e., identify opportunities to recycle materials within their own industry or establish partnerships with other industries.)[160] Recycled single-use drums and other containers can reduce waste and associated costs as well as raw material demand.[161] Recycled water reduces energy demand from pumping new water in and out and reduces the amount of treated oily wastewater released into the local watersheds.[162] Internal gas capture and recycling systems, especially in industries with high GWP gases, will minimize quantities of fresh gas flows and reduce fugitive emissions.[163] Onsite closed-loop recycling systems to reuse scraps produced in manufacturing processes can reduce the quantity of needed raw materials and reduce emissions 10-15%.[164]

Automation: Manual inventory management is inefficient. Automated storage and inventory optimization with artificial intelligence can improve space utilization and decrease energy usage 10-15%.[165] Automation can optimize workflows: improved efficiency, optimized material usage, and minimized waste, which cuts energy use 5-10%.[166] Smart sensors offer real-time monitoring of energy consumption, gas leakages, or other inefficiencies at each stage of production, which can reduce energy consumption by 3-7% while improving safety.[167]

Process Changes: There are many opportunities to reduce energy and material consumption through redesign of processes; innovative techniques; or switch to biobased or less environmentally harmful materials. Many processes can receive evaluation of their heat consumption through energy auditing. Some processes may need a lower volume or temperature of steam than currently supplied. It's important to determine whether there are process changes, opportunities to redesign processes, or existing equipment settings to reduce steam demand that can lower fuel consumption.[168]

Adopting lightweighting, which involves re-designing products to use less material while maintaining their strength, can lead to 5-15% reduction in material processing energy consumption like forging.[169]

Additive manufacturing may not be suitable for all fabricated metal manufacturing applications, but it is a process that 3-D prints metal components, reduces material usage by up to 50% and cuts heating emissions.[170] Thin slab casting of steel involves pouring thinner layers of steel rather than rolling out thicker slabs of steel. This process, while it requires major facility upgrades of around $50 million, could lead to up to 75% in energy savings. [171]

There are also opportunities to switch what type of material is used from high energy or GWP materials to relevant alternatives. Some inhaled anesthetics have high GWPs.[172] Lower-GWP anesthetics (e.g., sevoflurane) and a policy of regional anesthesia when appropriate, followed by intravenous anesthetics, when possible, will reduce emissions by 5-10%.[173]

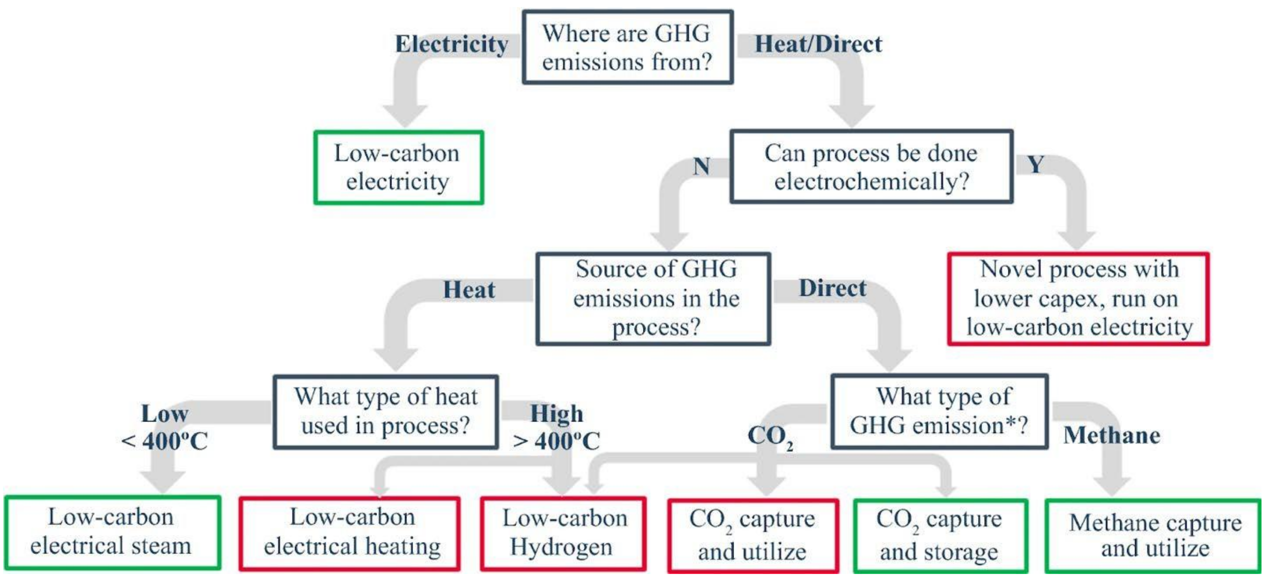
Lastly, clinker, which is a key component of cement, is currently made by heating limestone and other raw materials to high temperatures in a kiln (calcination). Reducing the clinker content in cement would decrease the amount of energy needed in this heating process. Clinker could be replaced with materials such as fly ash, slag, or calcined clay. This could reduce emissions due to cement manufacturing by the same percentage as clinker reduced.[174]

7.4.4.3. Industrial Electrification

Electrification means a transition to electric versions of current processes. There are two central opportunities to electrify industry: process heating and machine drives. The U.S. DOE Electrified Processes for Industry without Carbon (EPIXC) supports innovative projects that aim to electrify process heating.[175]

Process Heat: Process heat is the largest source of industrial energy consumption. Whether from boilers, furnaces, or incineration chambers, industry needs heat. Currently, there are commercially available electric boilers and heat pumps that can replace fossil fuel-based heating systems used for low temperature processes (<150°C). This can reduce emissions 45-70%.[176] High temperature processes, however, need more time for development and deployment. By 2050, thermal storage, multi-process heat pumps, electric boilers, resistive heating, inductive heating, and microwave heating will be commercially viable for higher temperature processes as well.[177] **Figure 26** shows a decision tree to determine if it is possible to electrify the heating process. This figure highlights the distinction between whether the process burns fossil fuels for heating or if the process itself produces GHGs.

Figure 26: Electrification Decision Making Tree



Electrifying Process Heat in Steelmaking: There are significant electrification opportunities at Cleveland-Cliffs' Cleveland Works facility. Electric Arc Furnaces (EAF) are already viable for secondary steel making. However, due to the nature of the steel that Cleveland Works produces, EAFs cannot entirely replace the existing blast furnace-basic oxygen furnace (BF-BOF) system. Instead, Cliffs can invest in a combination of direct reduced iron (DRI) and EAFs. In the short- to medium-term, Cliffs could shift BF #6 at its Cleveland Works facility from BF-BOF to natural gas DRI. In 2020, Cliffs opened its new Toledo DRI facility, which uses natural gas to reduce the iron oxide and heat the ironmaking process.[178] This process significantly reduces GHGs and emissions of air pollutants compared to the coke-based steelmaking. This approach also lays a foundation for complete decarbonization down the road. Cliffs constructed the Toledo DR Plant to run on a 30% hydrogen/70% natural gas blend at any time, and it can flip this blend to 70% hydrogen with minimal upgrades.[179]

Hydrogen-based DRI (H_2DRI) likely offers the best pathway to net zero steel production in the Cleveland-Elyria MSA. This process is currently used in Sweden with a technology called HYBRIT (Hydrogen Breakthrough Ironmaking Technology), and Volvo tests the steel for automotive purposes.[180] Currently, it does not make commercial sense to switch to H_2DRI, given the high upfront cost of construction and the price premium for green H_2.[181] This system, which provides a path to decarbonization, should be commercially viable to replace both BF-BOFs at Cleveland Works when the time comes to reline BF #5 in 2042.[182] Cliffs has already conducted three successful hydrogen injection trials its blast furnaces, and it has invested in a hydrogen pipeline at its Indiana Harbor Number Seven blast furnace.[183] The company has also previously said that it hopes to convert the Cleveland Works facility from coke to hydrogen.[184] Public sector and large private sector actors can support the shift to zero-emissions steel production by signing agreements to purchase green steel in the short- to medium-term to help overcome its cost premium and ease the path to full commercialization. While green steel currently costs more than traditional steel, BloombergNEF estimates that it could cost 5% less by 2050.[185]

If Cliffs decides not to convert Cleveland Works to DRI due to a lack of green H_2, it could shift to molten oxide electrolysis (MOE) by 2050.[186] Boston Metal developed this system to use electricity to directly produce steel from iron ore via a single step, zero carbon process. Because it relies on electricity, it removes the need for H_2 production, transportation, and storage onsite, and can use lower grades of iron ore than DRI can use. Boston Metal is set to open a demonstration plant in 2026 to showcase commercial viability of the technology. While this technology is simpler and more straightforward, in theory, it remains decades away from commercialization, and it may not be a viable for meeting the MSA's 2050 net zero target.

Machine Drives: Industry also uses fossil fuels to operate machinery in compression, grinding, milling, or pressurizing. Electric alternatives consume less energy than traditional systems and could lead to at least 10% emissions reductions.[187]

7.4.4.4. Alternative Fuels

Electrification cannot serve as a replacement where fossil fuels are used for the industrial process itself; alternative fuels are a consideration. Some anodizing and coating processes may need high temperature fast drying, which electric systems cannot fully replace. This would be one case where hydrogen-fired drying would be useful.[188] Chemical manufacturing uses fossil fuels as a feedstock for chemical reactions. These are cases where electrification cannot replace the chemical reaction taking place. Alternatives such as green H_2, biomass, consumer waste, or manufacturing waste can be used as feedstocks.[189]

H_2DRI and EAFs can decarbonize integrated steel production. This would be a massive investment, as it would require H_2 production onsite (50 kg H_2 per ton of steel) or transport via truck or pipeline. However, DRI uses 39% less energy than a blast furnace, so apart from the direct reduction in CO_2, there would be additional energy savings associated with the switch.[190] Cliffs could begin this DRI conversion now, as transition from coke to natural gas DRI can provide a bridge to full green steel production, as noted above.

7.4.4.5. Carbon Capture, Utilization, and Sequestration (CCUS)

It is possible to capture CO_2 either from a point source (e.g. smokestack) or directly from the air. One can then utilize or permanently sequester this carbon. This section outlines opportunities for point source capture and highlights the need for a direct air capture (DAC) facility within the region to achieve net zero targets.

Point capture: Because certain industrial processes, such as calcination for cement making, directly release CO_2, carbon capture technology in the flue gas system can reduce total emissions of the cement sector by 65%.[191] For industries where CO_2 makes up 10% or more of the exhaust gas, users could capture CO_2 through scrubbers at rates of up to 95% efficiency.[192] The CO_2 concentration is crucial to make capture economically feasible, and the higher the concentration, the more economic sense it makes to capture it.[193] Chemical manufacturers in the region do not emit enough to justify transportation and sequestration, but there may be smaller utilization opportunities interested in smaller quantities of CO_2 (e.g., cement sequestrations).[194] Appendix A offers a detailed study of carbon capture at Cleveland Works, though this approach represents a far less viable path to decarbonization at the facility, given the considerable technical and logistical challenges.[195]

Direct air capture: DAC takes CO_2 from the air at 100 times the rate of reforestation. The technology currently exists but is expensive and requires large amounts of clean energy to operate.[196] Regional DAC facilities co-located with sequestration sites or CO_2 utilization industries can help decarbonize hard-to-abate industries. Throughout the country, there are some industrial scale DAC projects under construction, with prices expected to decrease enough for more widespread adoption by 2050.[197] This provides both an opportunity for new industry creation and contributes to net zero goals throughout the rest of the MSA. Current technologies can capture 500,000 $MTCO_2e$ per year, but this should improve by 2050.[198]

Utilization: Once captured, CO_2 can provide feedstock for carbon-based chemical production in a closed-loop manufacturing process.[199] It can be used in cement making through calcium looping, where the CO_2 reacts with calcium oxide to form calcium carbonate, which can then be recycled through the calcification process. Captured CO_2 can also be used to cure concrete to make the concrete stronger and sequester the CO_2.[200] There are also specialized industries that develop unique uses for captured CO_2 streams, such as sustainable aviation fuel.

Sequestration: Even at commercial scale across the carbon management value chain, the utilization portion of CCUS is projected to account for only 10-15% of captured emissions by 2050 for the use of CO_2 in products that support climate goals.[201] The remainder of captured emissions require geological sequestration. For such large volumes of CO_2, pipelines are expected to be the most economical and efficient mode of transport.[202] In addition to sufficient capacity to store the volume of CO_2 captured, a suitable storage site must have adequate permeability. CO_2 is stored underground as a fluid. The more permeable the rock formation in which the CO_2 is stored, the less energy required to overcome resistance to fluid flow during injection. A detailed case study for CO_2 capture at Cleveland Works is laid out in Appendix A, though CCS may not be a viable approach to decarbonizing the facility, as noted above. Appendix A also includes an evaluation of potential pipeline routes and potential locations for geological sequestration to better inform any future planning processes. As the Appendix explains, any potential CO_2 transportation or sequestration work should include substantial community engagement, buy-in, and benefits agreements.

7.4.4.6. Industrial Renewable Energy

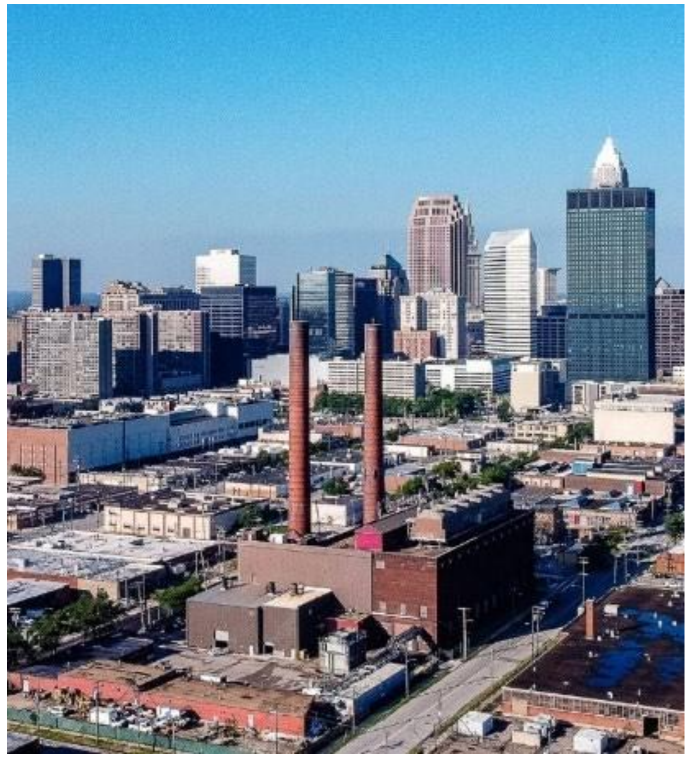
Increased onsite energy production at industrial facilities would reduce electricity costs, improve electricity resiliency, and can reduce the grid impact of electrifying industries. This section focuses on combined heat and power (CHP) systems and conversion of district heating to district geothermal systems.

CHP: CHP is a technology that generates electrical energy as well as thermal energy. CHP systems can generate enough electricity to exceed an operation's electricity needs. In some cases, CHP systems send electricity back to the grid. Cleveland Works installed a 137 MW CHP generator that produces most of the plant's electricity.[203] There are currently no examples of CHP systems used in industrial applications in the Cleveland-Elyria MSA outside Cuyahoga County, but CHP systems are candidates for other manufacturing applications.[204]

District Geothermal: District heating and cooling networks are currently in place in downtown Cleveland and around University Circle in Cleveland. These systems heat and cool buildings with a central steam generation facility and a network of interconnected, underground pipes. Retrofits of existing district heating for geothermal district heating that utilizes geothermal energy would remove the reliance on natural gas-powered steam generation and drastically reduce emissions.[205] Heat suppliers that use steam-based systems, as in the case of both Cleveland Thermal and the Medical Center Company (rather than water-based systems) would have to change to a water-based network. They can replace existing steam lines with insulated hot water pipes, replace steam-based radiators, and upgrade control systems.[206] Additionally, they would establish geothermal resources (i.e., drill boreholes and install ground heat exchangers) to transfer thermal energy between the earth and the district energy system.[207]

7.4.4.7. New Industry Support

Industrial decarbonization offers many opportunities for new industries to emerge in the Cleveland-Elyria MSA.


Corix Cleveland Thermal, Source: Corix

Electric Heating: Process heat electrification is crucial for decarbonization, as heating is the largest source of industrial emissions.[208] To support the massive number of electric heating units that will be necessary, the region should encourage manufacturers of electric boilers, heat pumps, inductive and resistance heaters, and other heating systems to relocate to the MSA.

Hydrogen: This region will require green hydrogen production facilities and net zero transportation and distribution of hydrogen to industrial end users.

Geothermal: To support the shift to geothermal water-based networks for district heating, the region needs to invest in geothermal systems design, maintenance, and components.[209]

CO_2 Utilization: While the Cleveland-Elyria MSA only has one industry, primary metal manufacturing, or steel making, that could readily justify the cost of CCS, there are smaller emitters that could collectively invest in the development of a CO_2 pipeline that connects to a utilizer or sequestration site. With CO_2 streams come opportunities for CO_2 utilization. Relocation of a utilizer to the region to collaborate with CO_2 suppliers will create circular industries in the region and create jobs. There are many demonstration projects that show ways to utilize captured CO_2. Examples include sustainable aviation fuel, CO_2 cement sequestration, solid long-term storage fuels, and electricity generation from ions produced in CO_2 absorption.[210]

Data Centers: Increased demand for data storage, cloud computing, and artificial intelligence is expected to continue. U.S. DOE projects a nearly 8% increase in electricity consumption due to data centers by 2028.[211] There is much guidance on comprehensive design and placement of these data centers to ensure that their energy consumption is renewable; utilization of natural cooling sources; and incorporation of heat recovery in the design.[212] One potential use for waste heat captured from data centers would be preheating in industrial applications.[213] This would require careful planning to co-locate data centers with waste heat utilizers.

7.4.5. Industrial Energy & IPPU Sector Benefits & Co-Benefits

This combination of energy efficiency measures, process efficiency measures, adoption of electrification, alternative fuels, carbon capture, and renewable energy methods can reduce GHGs across the industrial sector by 92% through 2050. **Table 26** shows the total emissions reductions by subsector.

7.4.5.1. GHG Emissions Reductions from Industry Measures

Table 26: GHG Emissions Reductions by Industrial Subsector

Subsector	2022 Emissions (MMT CO2e)	2050 Emissions (MMT CO2e)	Percent Reduction
Primary Metal Making	4.55	0.24	95%
Cement, Concrete, and Asphalt Manufacturing	0.65	0.04	94%
Fabricated Manufacturing	0.51	0.07	86%
Pipeline Transportation	0.34	0.15	55%
Chemical Manufacturing	0.29	0.03	90%
Steam Generation	0.19	0.01	95%
Hospitals	0.14	0.05	66%
Paper Manufacturing	0.07	0.007	89%
Total	**6.8**	**0.59**	**92%**

7.4.5.2. Co-Benefits from Industry Measures

Decarbonization of industrial processes and operations has many benefits in addition to a reduction in CO_2. It is also possible, through decarbonization, to abate other, more harmful emissions. This directly improves public health; reduces noise and vibration to make work environments safer; and improves water usage efficiency to decrease the amount of industrial wastewater. New industrial support will create job opportunities in the region that are discussed in depth in Workforce Planning Analysis (please see Chapter 12).

Public Health: The CRDF team estimated the relationship between CO_2 emissions and emissions of criteria air pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and $PM_{2.5}$ from the US EPA's National Emissions Collaborative Emissions Modeling Platform.[214] **Table 27** illustrates these benefits, showing total avoided health costs worth nearly $250 million annually by 2050. Additional information about health benefits for the entire state of Ohio from emissions reductions appears in Appendix A.

Table 27: Annual Air Quality Co-Benefits from Industry Sector Measures (2050)

Subsector	Reduction in SO_2 (Tons)	Reduction in NO_x (Tons)	Reduction in VOCs (Tons)	Reduction in $PM_{2.5}$ (Tons)	Avoided Health Costs
Primary Metal Making	1,307	2,206	412	996	$61.1 million
Cement, Concrete, and Asphalt Manufacturing	419	880	183	346	$128.3 million
Fabricated Manufacturing	4.33	253	431	65	$14.9 million
Chemical Manufacturing	46.9	298	663	97.6	$37.2 million
Hospitals	0.82	102	7.22	11.6	$4.4 million
Pipeline Transportation	0.09	77.1	29.3	2.74	$386,000
Paper Manufacturing	0.32	60.9	210	4.60	$2.9 million
Total	**1,778**	**3,877**	**1,936**	**1,524**	**$249.2 million**

Noise and Vibration Reduction: According to the Industrial Acoustics Company Comparison Examples of Noise Levels, steel mill operations are at around 110 decibels, which is the average human pain threshold. [215] Electric alternatives are, on average, nine decibels quieter than their diesel counterparts. This may not seem like a significant change in noise pollution, but in many cases, it would take 20 electric machines to create the same noise level as a diesel machine.[216] Electric alternatives equipment would make safer work environments and surrounding communities because they allow workers to better hear one another and protect themselves from dangerous noise levels.

Water Quality Improvements: Improved resource management at a facility; investments in more efficient machinery; and water recycling systems installation and leak detection equipment can reduce the amount of water consumed and reduce the amount of polluted water that returns to local waterways. As discussed earlier in this section, Cleveland-Cliff's Cleveland Works facility installed a water recycling system that reduces the amount of oily wastewater pumped into the Cuyahoga River.[217] In 2023, they also began to install a skimmer that reduces water consumption by 23 million gallons per year.[218]

7.5. Transportation & Mobile Sources Sector

Transportation and mobile sources accounted for 29% of GHGs within the Cleveland-Elyria MSA during 2022. MSA decarbonization needs this sector to be more efficient, accessible, and environmentally sustainable. While the scale of the challenge is substantial, transformative change in how people and goods move is not without precedent. From the advent of early, mass-produced automobiles (e.g., Model T) to the rise of rideshare platforms such as Uber and Lyft, disruptive innovations have continually reshaped transportation to overcome barriers and deliver widespread benefits.

7.5.1. MSA Context

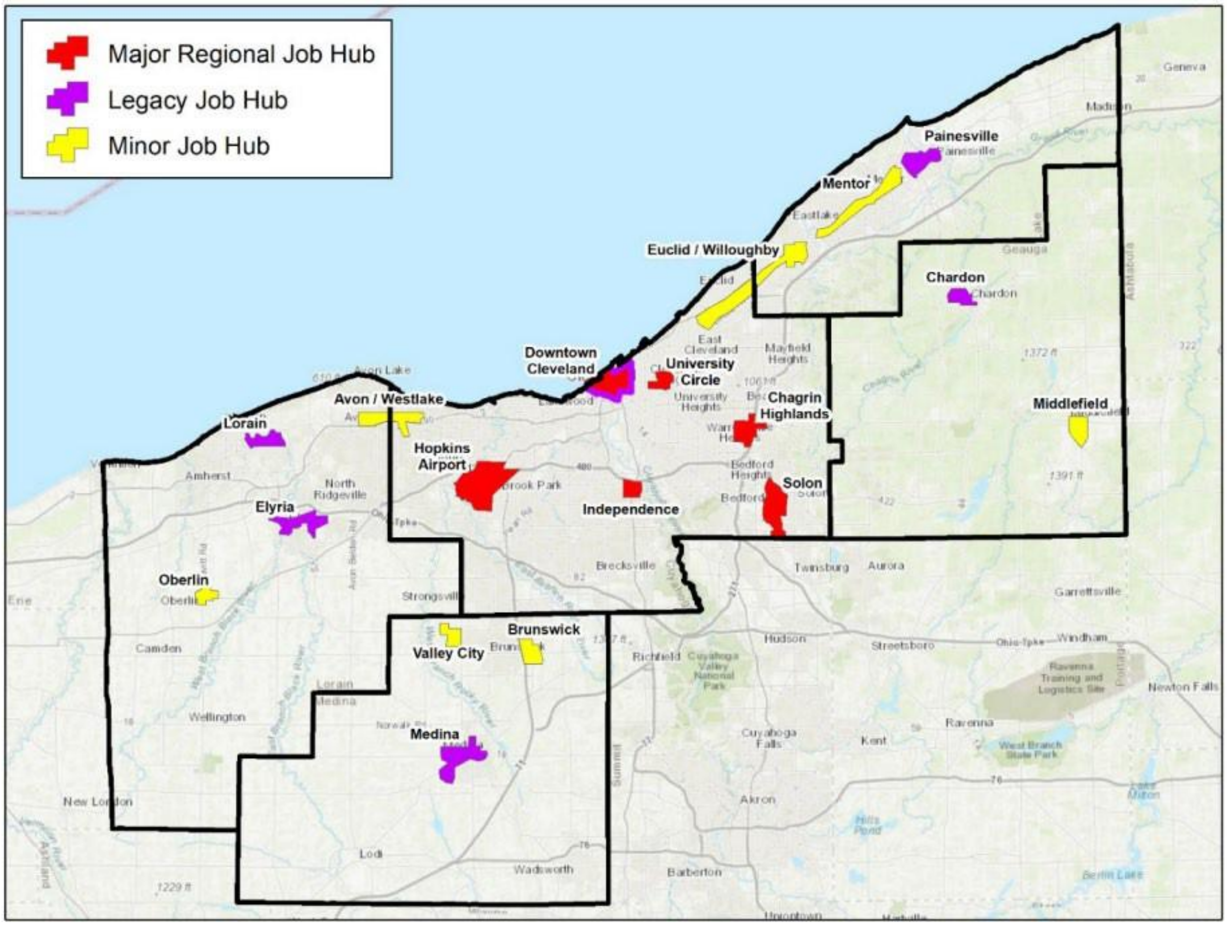
Two priorities form the foundation of transportation decarbonization: 1) reduce vehicle miles traveled (VMT) to move people and goods; and 2) transition to zero-emissions vehicles (ZEVs) and fuels.[219]

VMT reduction centers on more convenient transportation through system-level design strategies that provide easy access to employment, community services, and recreational opportunities. These strategies help minimize unnecessary travel while they fully address mobility needs. Local and regional land-use decisions and the design of communities and mobility networks affect travel choices. Reduced emissions and improved safety, traffic flow, and overall quality of life require thoughtful land-use planning, more efficient freight logistics, and the adoption of emerging practices such as telecommuting and the collaborative economy.[220] Together, these strategies can also strengthen connectivity and accessibility in communities that have traditionally faced disadvantages.

The region's legacy transportation network is primarily designed for industrial access and automobile travel. While Cuyahoga County has maintained its public transit infrastructure, including the GCRTA's rail and bus systems, the surrounding counties have more limited transit options and most residents are car dependent. Unlike denser MSAs, driving remains the dominant mode throughout the Cleveland-Elyria MSA due to expediency and convenience.

The City of Cleveland and Cuyahoga County have experienced population decline and suburban expansion over decades, while Geauga, Lake, Lorain, and Medina Counties have seen varying patterns of growth. This has created a spatial mismatch in the region between where employees live and where they work. As **Figure 27** shows, each of the MSA's six major job hubs is in Cuyahoga County, which attracts most home-based work trips from its neighboring counties.[221] The MSA's highway system, which was built to accommodate an anticipated population significantly larger than the current population, makes it easy for people to drive to these job hubs due to excess roadway capacity.[222]

Figure 27: NOACA's Major Regional Job Hubs



The Cleveland-Elyria MSA must make a strategic shift towards high-quality transit and active transportation networks that enable genuine mode choice. Such investments in high-quality infrastructure can enable mode shift. When integrated with system-level design strategies, alternative travel modes can enhance access for people and businesses while they decrease reliance on energy-intensive travel. The MSA can further improve transportation efficiency through innovative technologies that address first-mile/last-mile connectivity. Additionally, smart policies and technology solutions, such as connected and automated vehicles (CAVs), can increase safety, affordability, and efficiency, but must be managed carefully to avoid unintended increases in travel demand.

Enhanced convenience and efficiency of transportation systems will facilitate the transition to ZEVs and zero carbon fuels across all travel modes. This includes light-duty vehicles (LDVs), medium- and heavy-duty trucks (MHDVs), buses, off-road equipment (e.g., agricultural and construction machinery), aviation, rail, and maritime transport. This strategy focuses on ZEV deployment, particularly BEVs and hydrogen FCVs, and low-carbon fuels. A net zero economy requires transition of new vehicle sales to zero-emission technologies across all modes of transportation and rapid conversion of older and higher-polluting fossil fuel-powered vehicles. This transition will also require addressing EV charging and clean fuel infrastructure needs to ensure reliable access for all users, including individuals, fleets, and businesses.

7.5.2. Challenges & Barriers to Transportation Decarbonization

Significant obstacles to transportation decarbonization include the MSA's extensive highway network, minimal congestion, and relatively low population density, which favor driving. Automobile-centric development patterns have created dispersed employment centers throughout the MSA, which make hub-and-spoke transit systems less effective and complicate cross-county commuting. Population shifts from the urban core to suburbs hinder transit planning. Additional obstacles include aging transportation infrastructure, funding constraints, jurisdictional fragmentation, and the need for substantial investment in EV charging and hydrogen fueling infrastructure to support vehicle electrification efforts.

The MSA faces several critical decision points in its transportation decarbonization efforts, including whether to prioritize VMT reduction versus vehicle electrification; how to allocate finite funding between maintenance and new infrastructure development; whether to focus development along existing transit corridors or expand service to growing suburban areas; and determination of appropriate governance structures for regional transportation planning. Additional decision points include the timing and scale of EV adoption, the selection of appropriate clean fuel technologies for different vehicle classes, and whether to revitalize historic interurban transit routes or develop entirely new systems.

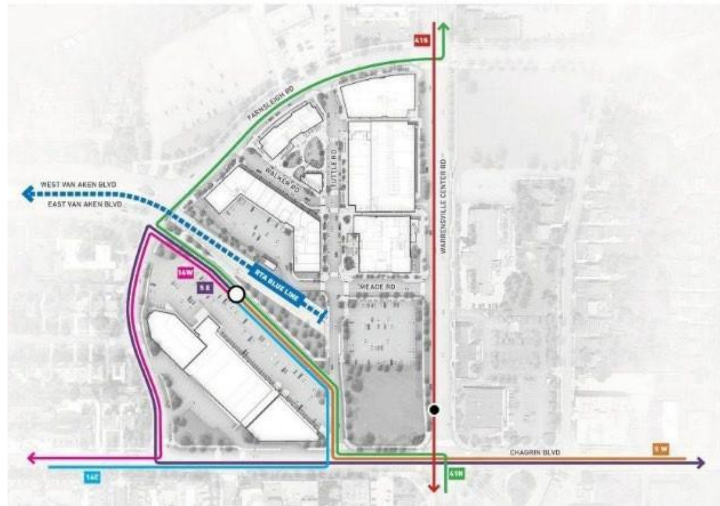
Pockets of the MSA experience substantial population growth and business development in core urban areas and first ring suburbs, in line with the recommendations of the Vibrant NEO 2040 plan. Growth areas include the Near West Side (e.g. Ohio City and Detroit-Shoreway) and University Circle in Cleveland. However, market forces and infrastructure investments continue to push development outward, which results in disinvestment and population loss in some city neighborhoods, on-going suburban expansion, and job dispersal.[223]

Efforts to increase active transportation are limited by the region's geography and climate. Lake effect snow, harsh winters, and the region's varied topography create additional barriers to active transportation options throughout the entire year. Increasing temperatures and longer heat waves could make summer cycling and walking more physically strenuous and potentially dangerous, while more frequent extreme precipitation events will likely create hazardous conditions. Warming winters and reduced snowfall may extend the biking and walking season; however, increased freeze-thaw cycles could accelerate pavement deterioration, which creates safety hazards and maintenance challenges. Communities may need to adapt infrastructure through shade structures, water stations, and better drainage systems along key pedestrian and cycling corridors. Some communities might also see behavior shifts, like people walking and biking earlier in the morning or later in evening during hot summer months, or increased demand for connections to cooling centers and public facilities with air conditioning.

7.5.3. Local Success Stories & Opportunities

Several local projects demonstrate how transit-oriented development, combined with the adoption of cleaner transit vehicles and charging infrastructure, can reduce VMT and GHGs. Together, these efforts illustrate how coordinated planning and low-emission transit solutions can offer replicable models for communities throughout the MSA.

The Van Aken District (Shaker Heights): This mixed-use, transit-oriented development was built after 20 years of planning and infrastructure improvements by the City of Shaker Heights. Previously, the area was home to two auto-oriented shopping strips, but the redevelopment includes a dense, residential community within walking distance of shops, offices and public spaces, located at the terminus of GCRTA's Blue Line train. It represents a TOD model that could be adapted at other rail stations, with a significant reduction in surface parking area. The transformation increased development density, with multi-story mixed-use buildings that replaced single-story retail. The co-location of uses in a compact area enables VMT reduction. This allows the development to significantly reduce transportation emissions through increased transit ridership, reduced trip generation through mixed-use development, and active transportation.



The Van Aken District, Source: MKSK

The West 25th Street District (Cleveland): This development in Cleveland's Ohio City neighborhood is particularly interesting as a TOD case study because it evolved organically around existing transit infrastructure over several years. The area is home to the West 25th-Ohio City Red Line Rapid Transit station, providing direct rail access to downtown Cleveland, University Circle, and Cleveland Hopkins International Airport, with excellent multi-modal connectivity including multiple bus routes and the HealthLine BRT system.

The neighborhood features pedestrian-friendly design with wide sidewalks, street trees, crosswalks, and traffic calming measures, plus a diverse mix of proximal land uses. The area has successfully preserved its historic character while it accommodates new

West 25th Street Bus Rapid Transit, Source: GCRTA & Stantec growth. It maintains an authentic neighborhood feel through public gathering spaces like Market Square Park and offers a range of housing options from renovated historic buildings to new mixed-use developments.

Two nearby public housing developments—Lakeview Terrace and Riverview Tower—play an important role in the area's economic diversity, as they provide stable, affordable housing options for low-income residents in a rapidly changing neighborhood. Though affordability remains a challenge, the proximity of Riverview Tower to the GCRTA Red Line and of both developments to frequent bus service provides transportation cost savings for lower-income residents, which partially offsets rising housing costs.

Lorain County Microtransit: The cities of Lorain and Elyria have partnered to launch an innovative, on-demand microtransit service, to improve access to efficient, affordable, and flexible transportation. Lorain County Transit partnered with Via in July 2024 to launch ViaLC, which provides on-demand transportation within Lorain and Elyria, or to Lorain County Transit fixed routes. An app with multimodal trip planning features helps riders connect to jobs, schools, and other destinations. Lorain County Transit has expanded its program to provide additional demand-response services, including Dial-a-Ride and the Oberlin Connector, with plans to further expand ViaLC as a core component of the county's transportation network.

Electric Transit Buses: Transit providers in the MSA make progress toward cleaner fleets through deployment of battery electric buses and charging infrastructure. In Lake County, Laketran has emerged as a statewide leader in electric transit. In 2021, the agency deployed 10 new 35-foot BEV buses, which transitioned 60% of its local fixed-route fleet to ZEVs.[224] To support these buses, Laketran installed six en-route fast chargers at its Wickliffe Transit Center, making it the first agency in Ohio to operate a bus rapid-charge depot. These investments have enabled continuous, all-day electric bus service across the county.

In 2024, GCRTA secured a $10.6 million Federal Transit Administration (FTA) grant to replace 10 diesel buses with BEV models.[225] The grant also funds the installation of three high-capacity EV charging stations at the Hayden Garage in East Cleveland, with full deployment expected by spring 2027. This project lays the foundation for future fleet-wide electrification and infrastructure upgrades.

In Lorain County, the City of Oberlin partnered with Lorain County Transit in 2024 to launch E-Bus, a small, accessible electric shuttle that operates all day on weekdays on a fixed loop throughout the city and surrounding township of New Russia.[226] Though modest in scale, the project serves as a replicable model for electric microtransit services in other towns and rural communities across the MSA.

7.5.4. Transportation & Mobile Source Emissions Reduction Measures

These measures will help the Cleveland-Elyria MSA realize immediate and sustained progress towards its GHG reduction targets. These measures largely correspond to the VMT Reduction, Light Duty Vehicle (LDV) Electrification, and Heavy Duty Vehicle (HDV) Electrification measures from the PCAP; however, this section builds upon those priority measures to provide a fuller suite of actions to decarbonize over the long-term. While on-road vehicles account for 90% of GHGs from the Transportation and Mobile

Sources sector, the MSA must have a strategy to eliminate the remaining 10% of emissions. Thus, the CCAP adds measures to address aviation, nonroad vehicles, rail transportation, and waterborne transportation.

Measures for this sector are grouped by transition to cleaner vehicles and fuels or VMT reduction. TOD has among the highest GHG mitigation potential of any VMT reduction measure.[227] As such, it forms its own distinct category of emission-reduction measures within the Transportation and Mobile Sources sector.

7.5.4.1. Transition to Cleaner Vehicles & Fuels

Two-thirds of transportation GHGs in the MSA are attributable to LDVs, while MHDVs, including public transit buses, make up nearly one-quarter (22.7%) of sectoral emissions. The remaining emissions stem from aviation (4.8%), water transportation (2.4%), rail (1.8%), and off-road vehicles (0.9%).[228]

The following section highlights measures to address the transition to cleaner vehicles and fuels within the transportation sector. These strategies include approaches for funding increased adoption. Comparisons are also made of regional emissions by 2050 under both a business-as-usual case, and under an optimistic case where the adoption of clean technologies accelerates in response to policy initiatives.

On-Road Vehicles: The following measures outline strategies to decarbonize on-road vehicles in Northeast Ohio. They are organized by their relative cost and readiness for implementation—starting with the lowest-cost, most immediately actionable efforts, and progressing toward longer-term initiatives that require greater planning, coordination, and capital investment. This graduated approach enables local governments to make near-term progress while laying the groundwork for deeper decarbonization over time.

Total cost of ownership (TCO) assessment of BEVs for local government fleets: TCO reflects the upfront costs, recurring costs, and end-of-life costs associated with owning and operating a vehicle. For certain vehicle classes and end-use applications, the TCO of BEVs is already lower than that of internal combustion engine vehicles (ICEVs).[229] Free tools such as the Dashboard for Rapid Vehicle Electrification (DRVE) Tool are currently available to help local governments identify BEV options that support decarbonization goals at a lower cost than ICEVs.[230]

Public education and outreach: Effective education and outreach campaigns are essential to familiarize both the public and fleet operators with BEVs and FCVs. Campaign strategies may include neighborhood workshops, ride-and-drive events, social media outreach, or informational kiosks at libraries and community centers. These initiatives help residents and fleet managers understand the financial and environmental benefits of electric vehicles and address common concerns around charging, refueling, range, and maintenance.

Local governments can host their own public demonstrations and develop accessible fact sheets tailored to their communities. Such campaigns require modest investments and can tap into municipal communications budgets, local sustainability offices, or in partnership with electric distribution utilities. Large ride-and-drive events cost around $27,690 each, while smaller ones can be held for less than $10,000.[231] Based on this estimate, a comprehensive outreach campaign with 8-15 events across the MSA would likely cost between $250,000 and $300,000.

Accelerate electrification of LDVs through increased participation in Climate Mayors EV Purchasing Collaborative: This collaborative is a national cooperative purchasing program designed to streamline and lower the cost of EV adoption for public-sector entities. Aggregated demand across hundreds of cities, counties, transit agencies, school districts, and other government units through the Collaborative enables participating jurisdictions to access competitively bid pricing on EVs and charging infrastructure.[232] This collective purchasing power reduces unit costs and simplifies procurement processes. Participation in the Collaborative also offers technical assistance and implementation support through a partnership with organizations such as the Electrification Coalition and Sourcewell, which enhances the capacity of local agencies to transition fleets strategically.[233] Expanded participation across the MSA allows more local governments to benefit from economies of scale, accelerating the turnover of fleet LDVs.

Replace Local Government Fleet ICEVs with BEVs on regular procurement schedules: While the federal government has eliminated tax credits for light-duty and commercial EVs, there are several use cases for local governments—including patrol cars and panel cargo vans—where BEVs are at cost parity with ICEVs.[234] EVs have operation and maintenance costs and require less downtime.[235] A 2024 study estimated that annual maintenance costs for LDEVs in Cleveland would be 53% less than an equivalent ICEV.[236] More precise and standardized estimates of EV useful life across vehicle classes and duty cycles will become increasingly important to better inform TCO calculations and EV procurement decisions.

Local EV Rebates for LDVs: There are currently around 16,000 passenger BEVs registered in the MSA.[237] By 2050, NOACA's travel demand model projects an LDV population of nearly two million across the MSA. To meet regional decarbonization goals, 99% of these vehicles would need to be electric by 2050.[238] This transition requires 21% annual growth of EV stock.[239]

A local EV rebate program could help meet this goal. Rebates are especially effective when delivered at the point of sale through participating dealerships.[240] This approach is particularly important for price sensitive low- and middle-income (LMI) households. Recent research indicates that a 10% reduction in EV purchase price can increase EV purchases for LMI households by 21%, which aligns with the regional growth rate needed for full electrification.[241] To be effective across a range of household incomes, a rebate of at least $2,000 is likely necessary, given EV pricing trends.[242]

To finance such a program, local governments could issue green bonds. Rebates would be applied directly by enrolled auto dealers as a line-item discount and reimbursed by the administering agency within 30 to 45 days. The program would be paired with the deployment of publicly owned EV charging stations, whose user fees (per kWh) could generate revenue to support bond repayment.

Green bonds—used to fund environmentally beneficial infrastructure—may be structured as:

- General Obligation (GO) Bonds, backed by municipal revenue and typically carry lower interest rates (~3.5% over 10 years); or
- Revenue Bonds, repaid solely from charger fee revenues, and generally priced higher (~4.5%) due to greater risk.

In a GO bond structure, EV charger revenues could be deposited into the general fund to help service the debt. **Figures 28** and **29** display the results of modeling annual surpluses or deficits under different charger deployment scenarios and user fee levels, including Ohio's current average EV charging cost of $0.40/kWh.[243]

Figure 28: Annual Surplus/Deficit from Public EV Charging (GO Bonds)

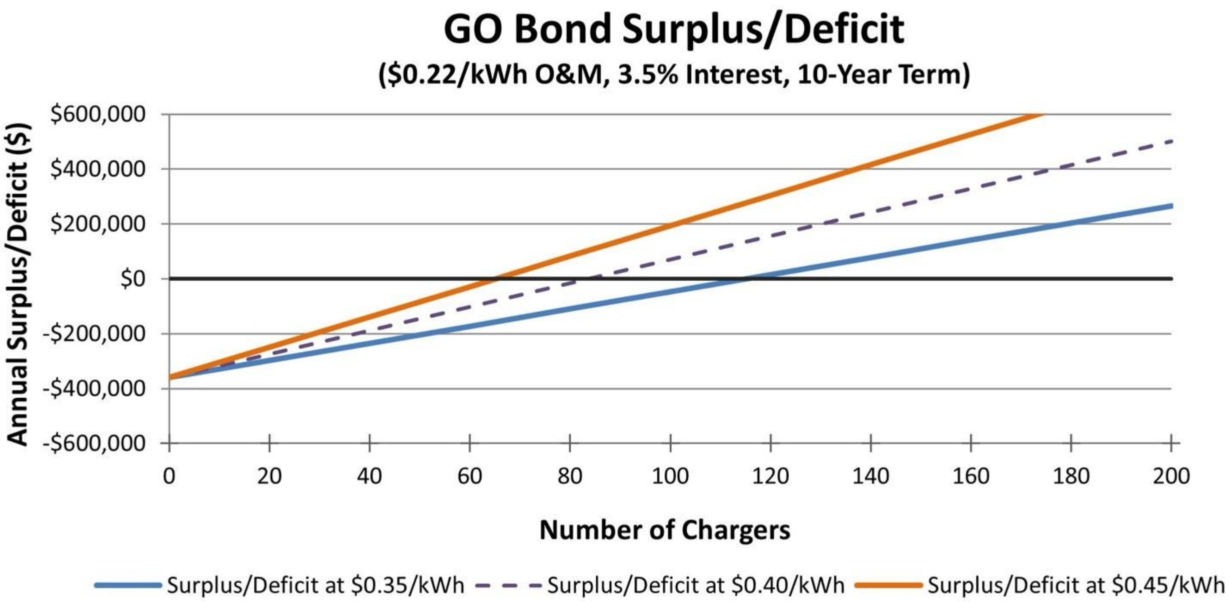
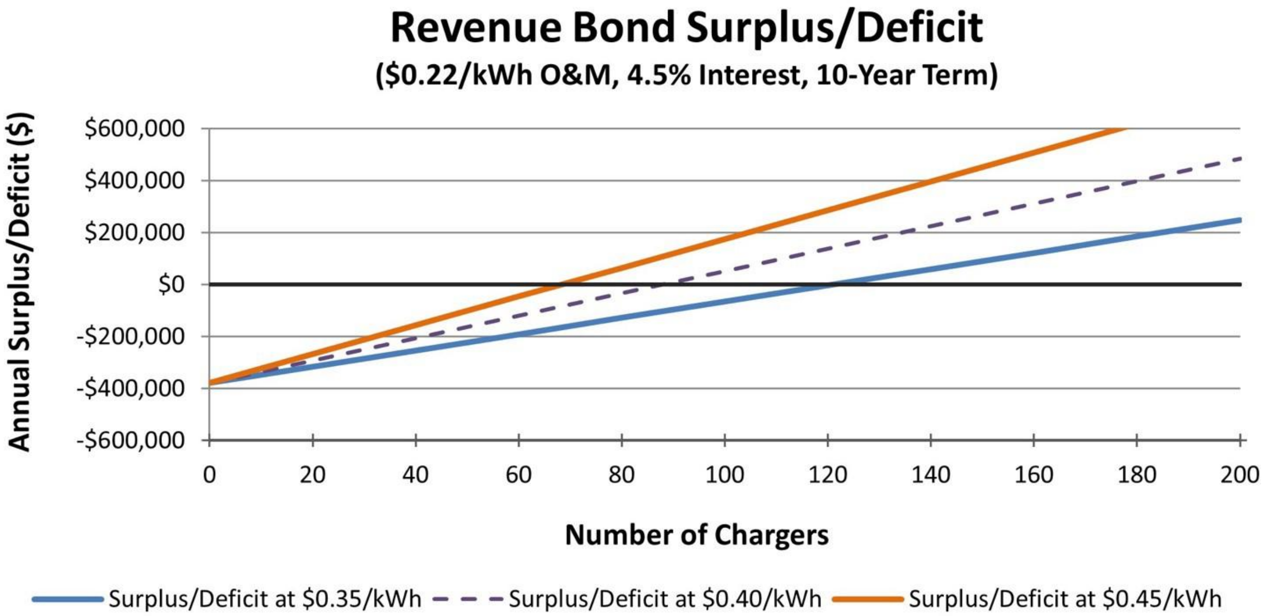


Figure 29: Annual Surplus/Deficit from Public EV Charging (Revenue Bonds)



*Local Strategies to Expand EV Charging: A*dequate EV charging capacity is necessary for all vehicle classes. For LDVs, which account for 75% of on-road GHGs, full electrification by 2050 would require the cumulative development of around 37,000 and 2,400 public Level 2 and DC Fast charging ports, respectively.[244] A charging network at this scale would require $358.3 million in cumulative investment through 2050.[245]

Local governments can play a pivotal role in expanding public charging infrastructure by leveraging planning authority, public assets, and local partnerships. One key strategy is identifying optimal charging locations using traffic data and freight movement patterns. Municipalities can support deployment by updating zoning codes to allow high-power charging in commercial and industrial areas, streamlining permitting, and incorporating EV infrastructure requirements into building codes, where possible. Coordinating with electric utilities is critical to ensure grid capacity and timely interconnection, especially for high-demand sites.

Local governments can also facilitate shared-use charging depots when they make public land available or co-develop hubs for multiple fleet operators. Public-private partnerships offer a path to scale when municipalities provide site access or utility coordination in exchange for guaranteed access to infrastructure. Regional collaboration with planning organizations can align investments across jurisdictions and support corridor-based approaches. Pilot programs can use public fleets—such as transit buses—to demonstrate use cases and generate valuable data for broader planning. Engaging logistics companies, community members, and labor stakeholders early in the process helps ensure charging hubs are well-sited, equitable, and supported by those affected. Even without federal funding, these locally driven measures can significantly accelerate the buildout of charging networks.

Aviation: The aviation subsector deals with the fuel consumed by aircraft. Aviation was responsible for 0.42 $MMTCO_2e$ in the MSA during 2022. This is a small but crucial component of transportation emissions. The solutions for decarbonizing aviation include electrification, innovative design, and adoption of sustainable aviation fuels, which will achieve a 95% emissions reduction for aviation.

Electrification: There are two main opportunities for electrification in aviation. First, gate electrification and pre-conditioned air from the airport will reduce jet fuel usage by parked aircraft (auxiliary fuels to power and cool the plane while boarding and deplaning). Second, small, local aircraft and small helicopters will be able to be replaced by 2050, reducing the emissions due to small, piston-engine aircraft that use AVgas.[246]

Design: New airplanes could be more efficient through their structure and materials. New plane designs with longer, thinner wings could reduce drag significantly, which reduces fuel burn by 10-30%.[247] There are projects that develop composite airframe technologies to make aircraft lightweight, which reduces the amount of fuel needed.[248] Other projects are focused on whether more of the aircraft powertrain can be electrified.[249] Finally there is software that models aircraft performance, which allows for more environmentally focused aviation design.[250] Adoption of these new designs significantly reduces the amount of fuel needed for each flight.

Sustainable Aviation Fuels: Many aircraft cannot be electrified due to the size, weight limits, and distances necessary for aircraft to travel. The largest solution to decarbonizing aviation is to replace jet fuel with sustainable aviation fuels (SAFs) that have 94% lower life cycle emissions than traditional jet fuel.[251] SAFs are effectively a direct substitute for jet fuel.[252] Currently, only up to 50% blends of SAFs are allowed in aircraft, but by 2030, 100% SAF should be available, with the goal of 100% SAFs by 2050.[253] There are programs that support the transition to SAFs such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), with the goal to reduce emissions on international flights to a baseline through SAFs and Lower Carbon Aviation Fuel (LCAF).[254] While SAFs manufacturing is not necessary within the region, it will be crucial to establish strategies to obtain the necessary quantities of SAF.

Waterborne Transportation: The subsector produced 0.21 $MMTCO_2e$ across the MSA and includes emissions from ports and ships that emit due to vessel propulsion, energy generation, cargo handling, and ground transportation. Typically, 60% of port emissions come from ships, 30% from land transport, and 10% from the terminal.[255] DOE lists four strategies to decarbonize ports and ships involved in the maritime transportation sector: electrification, alternative fuels, optimization of technology, and efficiency strategies, which will reduce emissions 95% from the maritime sector.[256] There are ports located in Cuyahoga, Lake, and Lorain Counties.

Electrification: There are opportunities for electrification in both port operations and small tugboats. The Port of Cleveland takes electrification seriously; it received a $95 million grant from the EPA for an electrification initiative to install electric charging infrastructure; support electric ground transportation equipment such as forklifts; install an electric heavy-lift harbor crane, build two electric tugboats, and prepare a warehouse for solar installation.[257] The Port of Cleveland needs 5-7 MW to completely electrify port operations, and the solar installation will cover 2 MW.[258] This is a significant undertaking and smaller ports in the MSA (e.g. Fairport Harbor) could adopt these strategies at a smaller scale. The DOE supports the development of battery electric boats across most marine vessels, but electrification is only expected to support short trips for harbor craft such as ferries and non-commercial vessels by 2050.[259]

Optimization of Technology: Vessels with low friction bottom coatings can reduce the amount of fuel needed to propel a ship by 10%.[260] Ports can provide power to ships during loading and unloading to reduce emissions from auxiliary fuel consumption while they idle in port.[261]

Efficiency Strategies: Establish best practices within the port and in the transportation of cargo broadly to reduce the amount of fuel used by ships and reduce the emissions from other transportation sectors. Inland towing (tugboats) can reduce emissions from trucks by nine (9) times and trains by 1.4 times.[262] Improved traffic flow to reduce idling time within a port can reduce emissions by 20%.[263] Reduced vessel speeds in ports also can reduce emissions by around 40%, depending on the vessel type and fuel[264]

Alternative Fuels: By 2050, the DOE projects that the majority of marine vessels will use sustainable alternative fuels for maritime vessels such as biodiesel.[265] In 2024, DOE announced plans for a program for defining and developing Sustainable Maritime Fuels through the Sustainable Maritime Fuel Grand Challenge, but there has been no additional follow-up.[266] The ships that enter and exit the Port of Cleveland and Lorain Harbor are self-propelled dry cargo, self-propelled tugboats, non-self propelled dry cargo, and non-self propelled tanker liquid barge.[267] If the tugboats only travel short ranges, they can be electrified, but otherwise, longer haul ships will require alternative fuels. Some fuels like biodiesel, which has net zero emissions, can directly replace diesel in ships, but other alternative fuels require new ship builds.[268] Full adoption of alternative fuels in the maritime sector is anticipated by 2050.[269]

Rail Transportation: Rail transport accounted for 0.16 $MMTCO_2e$ emissions across the MSA in 2022. Rail encompasses the emissions from locomotives and other rail transport equipment that use diesel, gasoline, or LPG. The emissions from rail transport are found in each county within the MSA except Geauga County. To decarbonize, these railways will need to replace existing fleets with renewable alternatives, whether through electric or hydrogen fuel cell electric alternatives. There are also opportunities for operational efficiency that will be especially useful for decarbonization in the medium term.

Electrification: Electrification of trains reduces emissions in this sector by 95%. Catenary electrification of rail involves powering rail transport with overhead electric lines. This method would make it so that recharging or refueling infrastructure would not be necessary. However, catenary lines costs around $71,000 per mile to build, which is traditionally cost prohibitive.[270] Alternatively, battery electric rail transport is viable. However, delays due to charging and range limits make them less attractive.[271] Combined frameworks of these two types of electrification allow for batteries to take over when there are no catenary lines and use of regenerative braking and other efficiency methods.[272]

Alternative Fuels: There have been feasibility studies for the application of battery electric versus hydrogen fuel cell electric rail transport, and there are situations where hydrogen is a preferable alternative. For longer trips or cases where there is insufficient recharging infrastructure or catenary electric for electric and battery electric rail transport, hydrogen fuel cell electric is an alternative.[273] Alternatives are preferable as they only cost one-third the price of hydrogen.[274] There are also opportunities for drop-in biodiesel fuels for rail that could immediately replace diesel, however, the assumption is that all rail transport will either utilize electricity or hydrogen by 2050.[275]

Operational Efficiency: Rail operators can cut emissions immediately through reduced idling, optimized scheduling, dynamic train brakes, and real-time analytics for efficient routing. These changes can reduce emissions by 20% and support longer-term technology transitions.[276]

Non-Road Vehicles: Non-road vehicles, which include forklifts, construction equipment, and airport ground support vehicles produced 76,200 $MTCO_2e$ in 2022. Of those emissions, 57% come from diesel engines, 31% come from gasoline, 11% come from liquefied petroleum gas, and 0.1% come from compressed natural gas.[277] Energy efficiency strategies, electrification, and the adoption of alternative fuels all help decarbonize non-road vehicles.

Energy Efficiency: High efficiency equipment (dredgers, conveyor belts, hoists) or retrofitting existing fossil fuel equipment with energy-efficient motors, variable speed drives, and automatic shutdowns can save 10-15% energy and reduce emissions 5-10%.[278]

Electrification: Non-road trucks, ground transportation at airports, construction equipment, drills, and loaders are currently dependent on fossil fuels, often diesel. Electrification of equipment where possible would be the most effective method for decarbonization, which completely eliminates emissions from this equipment.[279] Construction equipment, ground transportation for warehouses and airports, open pit mining equipment, and facility forklifts can all be electrified.[280] The US DOT's Voluntary Airport Low Emissions Program (VALE) funds projects for gate electrification, charging stations for ground vehicles, geothermal systems, and solar hot water systems at airports.[281]

Alternative Fuels: Some applications are not conducive to electric equipment because it may be too difficult to install charging infrastructure, or, as in the case of Cleveland's Cargill salt mine, equipment may never return to the surface for recharging. At Cargill, mining equipment is constructed under the lake and never returns to the surface. In this case, fuel-switching would be a more feasible option to transition mining equipment away from fossil fuels. Green hydrogen fuel mining equipment allows for a reduced dependence on fossil fuels; makes the air within the mine cleaner; and reduces noise and vibrations in the mine to improve mine safety.[282] While equipment varies, the average non-road equipment requires around 10 kg per hour of operation.[283] Some operations may find hydrogen fuel cell electric forklifts more suitable, but currently the trend is a greater uptake in battery electric forklifts.[284]

7.5.4.2. Near-Term VMT Reduction Strategies (2025-2030)

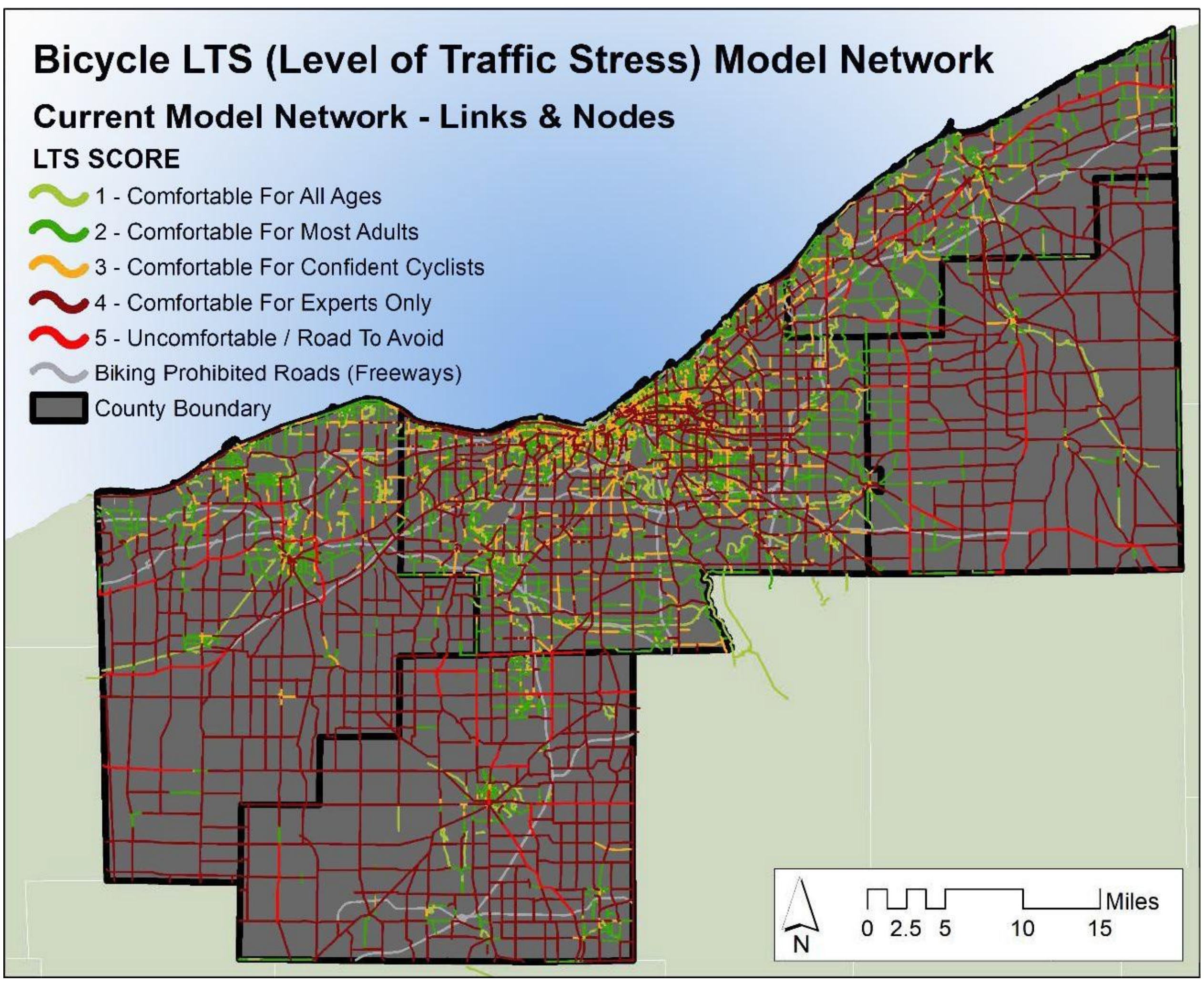
VMT reduction targets in the near term include a 15% reduction in passenger VMT from baseline levels; 5% improvement in freight efficiency measured in ton-miles per gallon; and 3% modal shift from truck to rail for eligible freight. As a target for urban areas, walking, cycling, or public transit could comprise 15% of all trips.

Measurement: A critical first step is already underway. NOACA measures and models VMT across all five counties to ensure accurate tracking of progress.

Bicycle Infrastructure: Currently, about 75% of existing bicycle infrastructure in the region consists of unprotected sharrows or conventional bike lanes, which primarily serve confident cyclists. Protected bike lanes attract a broader demographic of users, including less experienced cyclists, families, and senior citizens. The National Institute for Transportation and Communities (NITC) studied six U.S. cities and found that protected bike lanes attracted riders who were otherwise "interested but concerned" about cycling, particularly women and families with children.[285]

NOACA's ACTIVATE Plan maps levels of traffic stress (LTS) across the MSA, as shown in **Figure 30**. The Plan notes that the most fundamental improvements to the region's bicycle network would be to create connected bicycle lanes with a LTS of 1 or 2. Low-stress connectivity can be used to evaluate and guide a bicycle network expansion.

Figure 30: NOACA Bicycle Level of Traffic Stress Model Network



Across the MSA, there are three primary barriers to low stress connectivity:

1. Natural and man-made barriers, such as freeways, railroads, and creeks;
2. Arterial streets, whose cross streets lack the combination of a low-stress approach and a safe crossing; and
3. Breaks in the neighborhood street grid, a common feature of newer developments that force traffic, including bicycle traffic, to use arterials to access local streets.[286]

To meaningfully increase cycling mode share, the region should prioritize fully protected facilities for 80% of all new bicycle infrastructure in Legacy Cities and First Ring Suburbs. Cleveland has a goal to complete 50 miles of protected bike lane network in the City by 2030. Some suburban jurisdictions in Cuyahoga County such as Lakewood, Cleveland Heights, University Heights, and South Euclid will also expand bicycle infrastructure.

These investments will help to establish replicable best practices in other MSA communities, including:

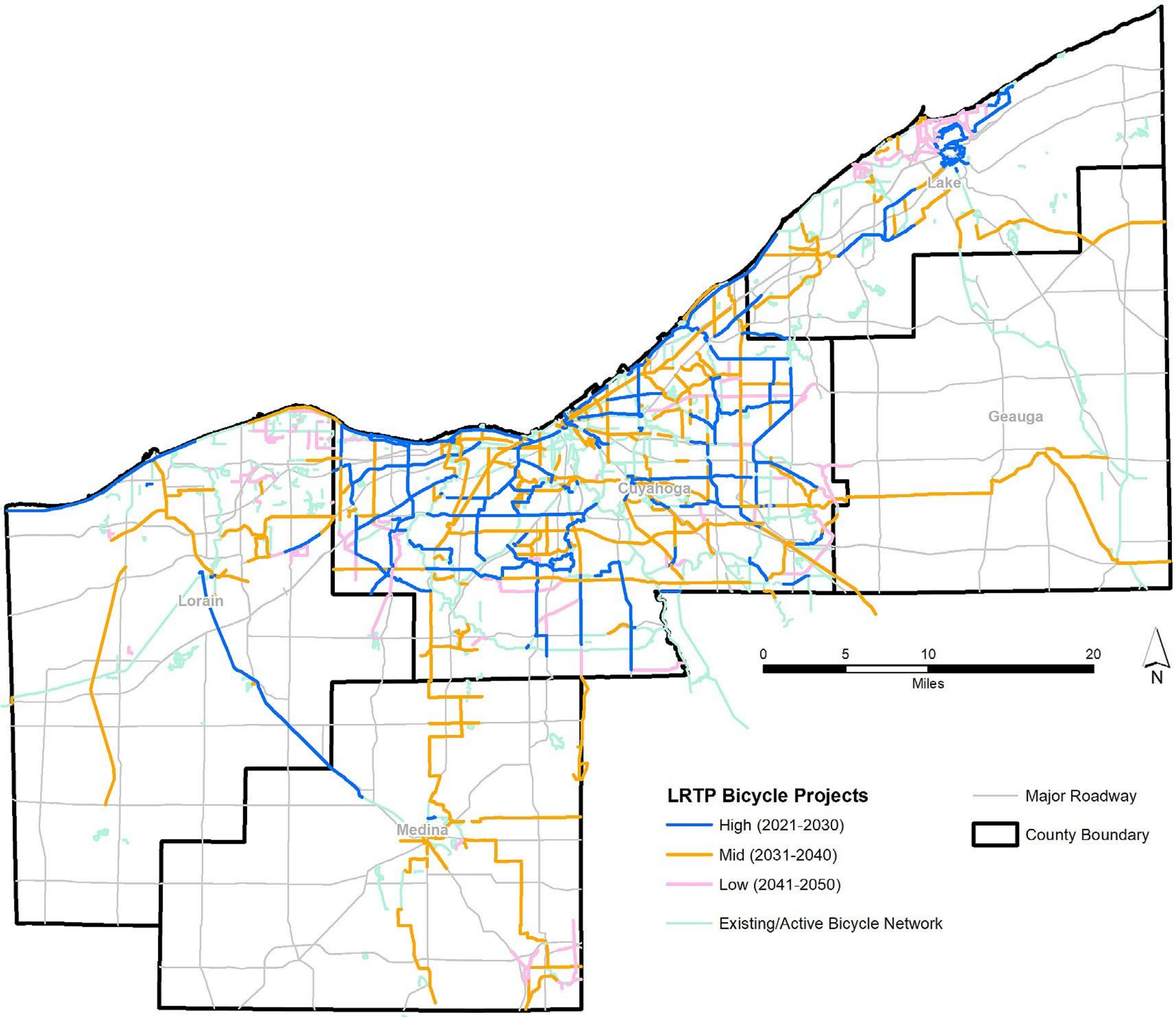
- Add protection to existing wide bike lanes where appropriate;
- Restripe and add new separated bike lanes through a quick build process; and
- Install neighborhood greenways signage and markings with strategically located speed tables or other traffic calming measures.

There tend to be fewer bike facilities in the outlying areas of the MSA; however, several communities have invested in bike infrastructure, including:

- The City of Lorain has an active transportation plan to encourage better walking and bicycling experiences in the city, including the installation of sharrows and buffered bike lanes, a Safe Routes to School program, and a pedestrian safety program with traffic signal and pedestrian improvements.
- The City of Mentor has implemented a bikeway system consisting of bike lanes and bike paths.
- The City of Medina has adopted a framework to guide multi-modal development throughout the City over the coming decades. In total, over 25 miles of multi-modal connections are proposed within this plan. The majority of the proposed multi-modal connections are off-road trails, although the city's proposed Southwest Connector will be a buffered bike lane. Medina aims to link residents to community assets, connect the existing trail network, and provide multi-modal access to all Medina residents within a half mile of their homes.

NOACA's long-range plan, w*eNEO2050+*, incorporates existing and planned bicycle projects to enhance regional transportation and mobility as seen in **Figure 31**. The plan aims to improve safety, accessibility, and the overall experience of bicycling and walking in the region. It recognizes the importance of the 50-year vision for trail development in the existing Cuyahoga Greenways Plan and also incorporates recommendations from the Vibrant NEO 2040 plan, which focuses on enhancing walking and cycling as transportation options.[287]

Figure 31: Existing and Planned Bicycle Projects (weNEO2050+)



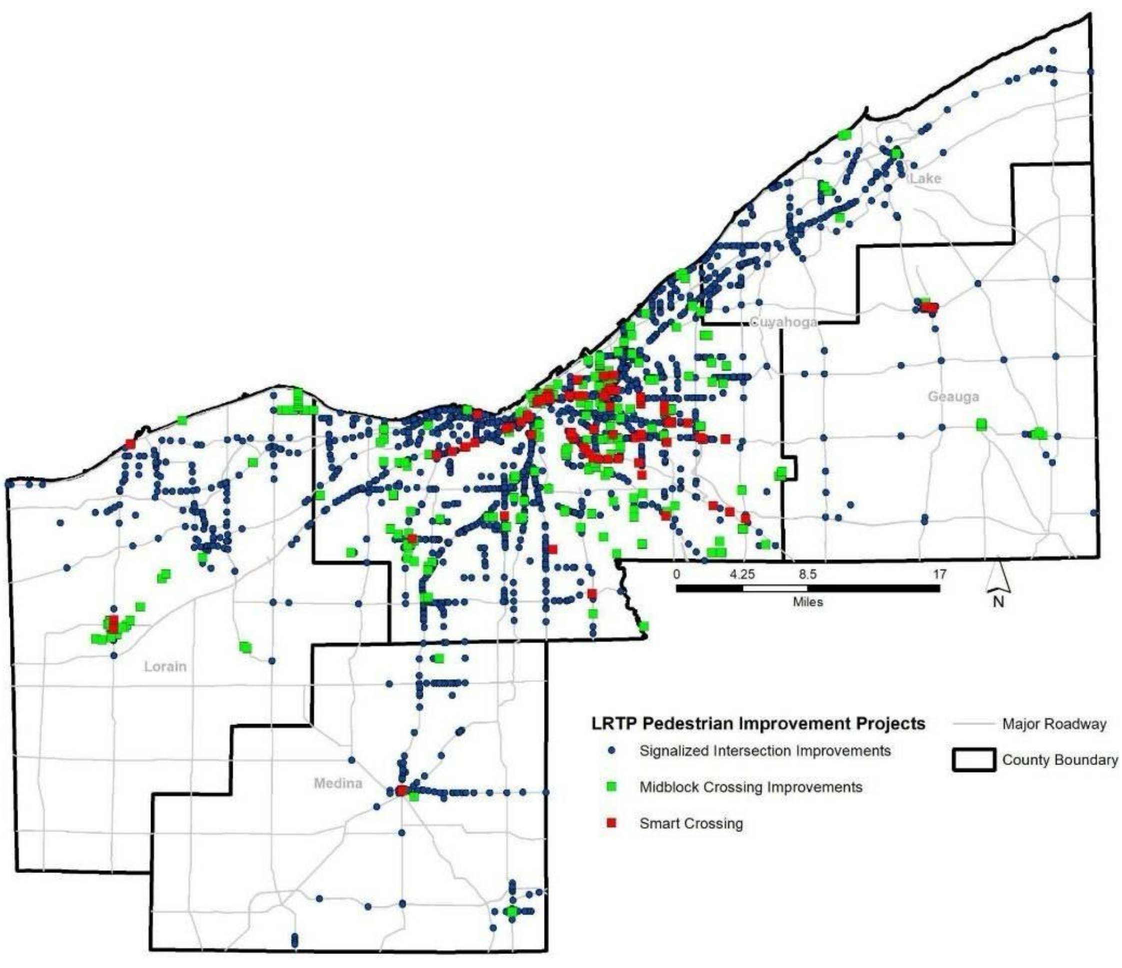
Bicycle infrastructure depends on connectivity. Currently, many bike facilities across the MSA exist as isolated segments, which limits their utility. New bicycle infrastructure projects should aim to connect at least two existing facilities, to create a more usable network that can reduce VMT for at least some trips, some of the time. Legacy Cities should aim for a maximum gap of 0.25 miles between bicycle facilities, while suburban areas can typically accommodate gaps of up to one mile and still maintain network functionality. The region should fill the gaps between disconnected segments and shift to more protected bike facilities to reduce transportation emissions through modal shifts.

Northeast Ohio's climate necessitates specialized four-season design considerations. To achieve measurable VMT reductions, bicycle facilities must remain usable year-round. This requires dedicated year-round maintenance plans for priority routes with mechanical clearing capabilities, all-weather surfaces resistant to freeze-thaw conditions, and adequate lighting to accommodate early darkness during winter months.

Pedestrian Infrastructure: Pedestrian infrastructure throughout the region needs to serve people of all ages and abilities, with ADA compliance as a minimum rather than maximum standard. Smart city technologies can be incorporated to prioritize pedestrian activity, particularly around schools, senior centers, and medical facilities, including a network of sensors that extend crossing times when needed and improve overall safety.[288] To enhance pedestrian comfort and safety, a maximum crossing distance of 30 feet should become standard, unless the street design includes a pedestrian island.

weNEO2050+ includes existing and planned pedestrian projects (see **Figure 32**), aimed at improving pedestrian safety and connectivity, while also fostering a more equitable and sustainable transportation system for Northeast Ohio. The plan aims to improve pedestrian safety by creating dedicated pedestrian facilities separated from vehicular traffic and addressing safety issues in high-risk areas. The plan emphasizes the importance of connecting pedestrian and bicycle infrastructure with transit systems and other modes of transportation to create a truly multimodal transportation network.

Figure 32: Pedestrian Improvement Projects (weNEO2050+)



NOACA's existing ACTIVATE plan aims to expand and improve the existing network of bikeways and walkways to increase the use of non-motorized modes. The RAISE plan also includes recommendations to improve pedestrian infrastructure and expand the complete streets network throughout the MSA. The plan also incorporates the development of EV charging stations, which can further contribute to pedestrian and bicycle-friendly infrastructure through reduced reliance on private vehicles.

Winter walkability presents major challenges in the region. Ideally, city and county public works departments would assume responsibility for sidewalk clearing on priority pedestrian routes throughout the MSA, especially near transit stops, schools, and healthcare facilities. New sidewalk construction could establish minimum widths of six feet to accommodate winter snow storage while maintaining accessible pathways. Slip resistant surface materials would improve safety in winter weather conditions.

Expanding Public Transit: Increased frequency of transit service would make buses and trains a more viable option for daily transportation. Cleveland and its inner-ring suburbs could target 10-15 minute headways on major corridors, seven days per week during peak travel times. Outer suburbs could aim for 20-30 minute headways during peak periods and 60-minute service during off-peak hours. Rural areas in the MSA could provide scheduled service two to three times daily, supplemented by an expansion of existing on-demand transportation options. The region's aging demographics, combined with longer working lifespans, may necessitate expanded paratransit services to ensure mobility for residents with disabilities.

weNEO2050+ includes a scenario (TRANSIT) that focuses on building a comprehensive multimodal transportation network centered on public transit. The foundation of this approach is the improved 2017 visionary rail network plan and the transit agencies' future bus/BRT network plans to develop a multimodal transportation system.

The rail network plan is complemented by existing transit agencies' future bus and Bus Rapid Transit (BRT) routes. To improve access to major employment centers and transit stations, the plan incorporates autonomous shuttle buses that would transport workers more efficiently throughout the region.

Fairness drives this scenario's design, with particular emphasis on serving communities that have historically lacked adequate transportation options. The plan aims to reduce transit service wait times (headways) in these underserved neighborhoods and establish a regional goal of limiting average commute times to major job centers via public transit. To support this transit-oriented approach, the plan encourages housing development near transit stations and major job centers to ensure a larger share of the 2050 workforce will live within five miles of these key destinations. Transit providers throughout the region, including LakeTran, Geauga Transit, and Lorain County Transit contribute to efforts to reduce VMT and GHG. GCRTA has adopted a plan for GHG reductions, which could serve as a template for other transit agencies in the MSA. A mode-shift to transit is part of GCRTA's climate action strategy.

Additionally, GCRTA aims to reduce greenhouse gas emissions in its bus fleet:

- Convert revenue buses to non-diesel (mostly CNG) by 2035.
- Expand an electric bus pilot study to 20 buses. Fleet electrification should be a priority for all transit providers in the region, although Geauga Transit and LakeTran have focused on propane-powered buses to reduce emissions and fuel costs.
- Phase out gasoline fueled non-revenue and paratransit vehicles; replace them with hybrid and electric.

Strengthen Regional Connectivity: There are limited opportunities for inter-county fixed-route transit, though a network of a few intercounty transit spines may be viable. Transit providers can focus on providing a combination of fixed route and demand responsive service that crosses county lines along these spines.[289] By 2030, the region should aim to significantly increase intercounty transit connections to major job centers, supported by new cross-county funding mechanisms for regional transit authorities. NEORide and EZFare are fare integration systems that allow riders to transfer between counties without paying multiple fares or navigating different payment systems. Bus rapid transit (BRT) should be extended strategically throughout the five-county region.

7.5.4.3. Mid-Term VMT Reduction Strategies (2030-2040)

The 2030-2040 period could include more ambitious goals for the region, including a 25% reduction from baseline for passenger VMT. This would be a substantial acceleration from the previous decade. Another goal is 10% reduction in freight VMT through combined efficiency improvements and modal shifts to rail and water transportation. If alternative fuel adoption reaches a critical mass in this period, 30% of the regional truck fleet could transition to electric or other low-carbon fuel sources. Active transportation could account for 25% of trips in urban areas and 15% in suburban communities, nearly doubling the previous period's targets.

Expand Public Transit Network & Transit-Oriented Communities: The mid-term strategy envisions a significant expansion of BRT lines throughout the region to create a comprehensive network that serves both urban and suburban communities and centers in outlying townships. These enhanced corridors would prioritize transit vehicles through dedicated lanes, signal priority, and strategic station placement; reduce travel times; and improve reliability. Some routes could align with historic electric interurban railway corridors that served Northeast Ohio in the early 20th century.

Regional connectivity could become a reality through the implementation of five intercounty transit connections that provide 30-minute peak service to effectively link employment centers, educational institutions, and commercial districts across boundaries. These connections would build upon early successes from the near-term (2025-2030) period and expand service frequency and coverage area. Major transit nodes should include robust micro-mobility options like e-bikes, scooters, and bike share programs to address the "last-mile" connection challenges that have historically limited transit adoption in lower-density areas.

Accessibility will be paramount in this period, with transit stops positioned no more than 0.25 miles from safe pedestrian infrastructure. This proximity ensures most transit users can safely and comfortably access services regardless of age or ability. The region could also complete the integration of transit and cycling networks, with 100% of transit vehicles equipped with bicycle accommodations like on-board racks or dedicated storage areas.

Comprehensive Active Transportation Networks: "Vision Zero" policy implementation across all five counties would establish a region-wide commitment to eliminate traffic fatalities and serious injuries. This shift in transportation planning philosophy would prioritize safety above vehicular throughput, particularly for vulnerable road users. NOACA's *Plan for Transportation Safety (SAVE Plan)* aims to save lives in the MSA by identifying actions to reduce the most severe crashes.[290] *SAVE* adopts the vision that traffic deaths and injuries are preventable through appropriate planning, policies and programs. The long-term goal is to reduce the number of fatalities and serious injuries 50% by the year 2040. A safer transportation network requires stakeholders address the interaction among the infrastructure, vehicles and the skill and behavior of travelers. The SAVE Plan incorporates a "6 E's" approach (**Figure 33**) into the safety planning process; authors acknowledge the key roles that engineering, education, enforcement, emergency response, evaluation, and equity all play to prevent severe crashes and save lives.

Figure 33: The Six Es of Transportation Safety

Ten (10) designated pedestrian priority zones in neighborhood centers throughout the region would enhance the pedestrian experience. These areas could feature enhanced crossings, reduced vehicle speeds, frequent transit service, wider sidewalks, and streetscape improvements to create vibrant, walkable public spaces that support local businesses and community interaction.

Legacy Cities and First ring Suburbs should create continuous pedestrian networks, which extend from transit stops and stations that serve residents of all ages and abilities. In this timeframe, the region could complete an additional 25 miles of all-seasons protected bicycle infrastructure specifically aimed at connecting urban and suburban destinations. This additional bicycle infrastructure allows for seamless bicycle commuting between residential areas and employment centers. Outer-ring suburbs could focus on eight-foot multi-use paths along 100% of connector streets to accommodate both pedestrians and cyclists in areas where separate facilities may not be feasible due to right-of-way constraints or lower density development patterns. These pathways would create safe active transportation options in communities that have traditionally been car dependent.

Rural areas could make significant infrastructure improvements with paved shoulders a minimum of four feet wide on all county and state routes. These enhanced shoulders would provide crucial space for cyclists and pedestrians in areas where dedicated facilities are less common, while they also improve roadway durability and safety for all users.

The mid-term period could culminate in the completion of a 150-mile regional protected bicycle network to connect all county seats with high-quality, all-weather bicycle infrastructure. The network could follow scenic corridors where possible to serve both transportation and recreational purposes while it showcases the region's natural amenities and strengthens connections between communities.

7.5.4.4. Long-Term VMT Reduction Strategies (2040-2050)

By 2040, the MSA could pursue substantially more ambitious targets as transportation systems and land use patterns evolve. Passenger VMT could be reduced by 30%, which represents a transformation in how residents move throughout the region. Freight VMT could decrease by 15-20% through continued efficiency improvements and further modal shifts to rail and water transport. Active transportation could become the predominant mode choice for many communities, potentially accounting for 40% of trips in urban areas, 25% in suburban communities, and 10% in rural centers.

Sustainable Funding Mechanisms: The long-term strategy should include a fundamental shift in transportation funding models. The region could establish VMT-based taxation systems to replace gas taxes, with differentiated rates for freight and passenger vehicles, given their varying impacts on infrastructure and emissions. ODOT has convened discussions on this issue, but implementation would require statewide action. This approach would provide sustainable revenue as vehicle efficiency improves and alternative fuels become more ubiquitous. Additionally, comprehensive road pricing mechanisms based on time of day, location, and vehicle occupancy might be implemented, which would create financial incentives that further reduce unnecessary trips and encourage higher-occupancy travel.

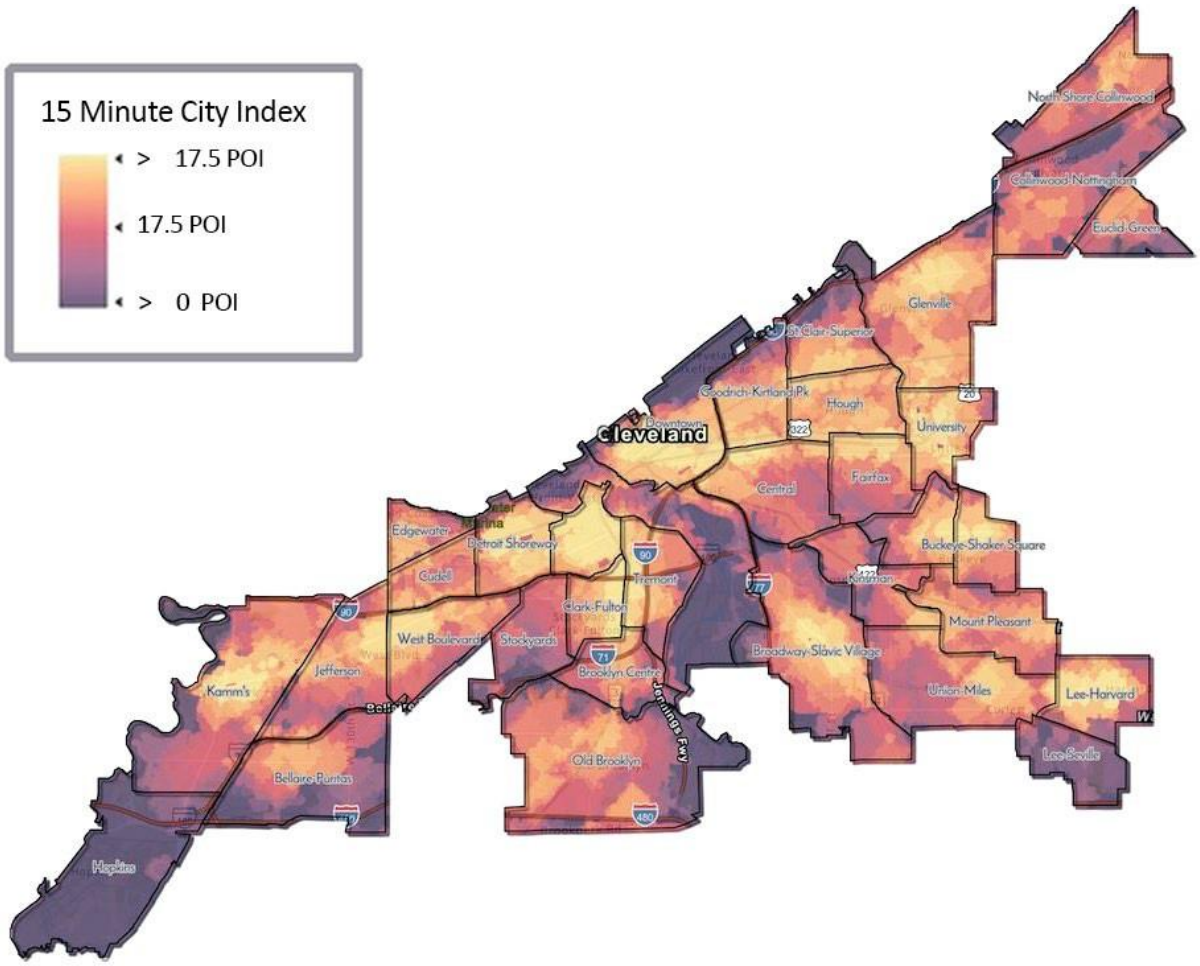
Enhanced Active Transportation Networks: Bicycle infrastructure could evolve into a new classification within regional transportation planning, with "bicycle highways" gaining recognition as a distinct infrastructure class. These facilities would prioritize direct connections between major destinations with grade separation at busy intersections and weather protection in key segments. Communities can shift away from LOS metrics to alternatives, in partnership with ODOT, under its Vulnerable Road User Assessment, fundamentally reshaping transportation project evaluation.[291]

This paradigm shift could support the development of an ambitious 300-mile network of weatherized, protected bicycle highways throughout the MSA. This network could include covered segments in urban areas, heated surfaces for winter travel, and intelligent lighting systems that respond to usage patterns. Every school district in the region could implement comprehensive SRTS programs, potentially eliminating the need for bus service within a one-mile radius of many schools. These initiatives, combined with previous efforts, will advance Vision Zero targets, eliminating serious injuries and fatalities for all road users.

Advanced Transit Systems & Transit-Oriented Communities: Long-term, the MSA should integrate an intercity rail station into the region's intermodal transit system, potentially enhancing Cleveland's connection to the national passenger rail network with high-frequency service to Chicago, Pittsburgh, Columbus, and Detroit. This connection might catalyze development around station areas and enhance the region's position in the Midwest economic corridor. Urban neighborhoods could evolve into "15-minute neighborhoods," where residents can access daily needs without stepping foot in a car. This concept could be realized in approximately 75% of urban areas throughout the region. The abundance of surface parking throughout the region provides an untapped "landbank" that communities can repurpose, with potentially 30% of existing parking converted to housing, open space, and commercial uses that enhance community vitality and increase tax base.

The Cleveland City Planning Commission has adopted a 15-minute city model, based around a 15-Minute City Index (**Figure 34**). This index highlights how many points of interest (e.g. daycares, cafes, grocery stores, libraries, schools, transit stops) are within walking distance.[292] Lighter areas indicate more points of interest (greater than or equal to 35 sites) while darker orange to purple areas indicate fewer points of interest (17.5 to 0 sites). While the 15-minute neighborhood model may not be feasible in many parts of the region, identifying nodes in all five counties where residents could choose a more compact and convenient lifestyle would help to reduce VMT emissions. By 2050, transit technology could advance significantly and potentially include automated transit vehicles that operate on dedicated guideways within major corridors. These systems would provide higher frequency, lower operating costs, and improved reliability. Rural areas might benefit from comprehensive on-demand mobility services utilizing smaller vehicles and flexible routing to connect residents to regional transit hubs and local destinations.

Figure 34: City of Cleveland 15-Minute City Index



Systems Transformation: The transformation of work patterns will likely continue, with potentially up to 50% of office workers on a remote or hybrid arrangement that significantly reduces commute trips.[293] This shift would allow repurposing of office space in downtown areas and suburban office parks for residential and mixed-use development. The region will require new housing to replace older residential structures that reach the end of their useful life, regardless of population trends. Developers should construct new residential units in areas of the region well-served by public transit to achieve VMT. This already occurs; one-third of new development in Cuyahoga County from 2019-2024 happened in TODs.[294] Development regulations could require VMT-neutral outcomes for all new construction, meaning any project that generated additional vehicle trips would need to implement mitigation measures to offset this increase. These measures might include funding for expanded transit service; bicycle infrastructure, affordable housing near employment centers; and regional mobility service contributions.

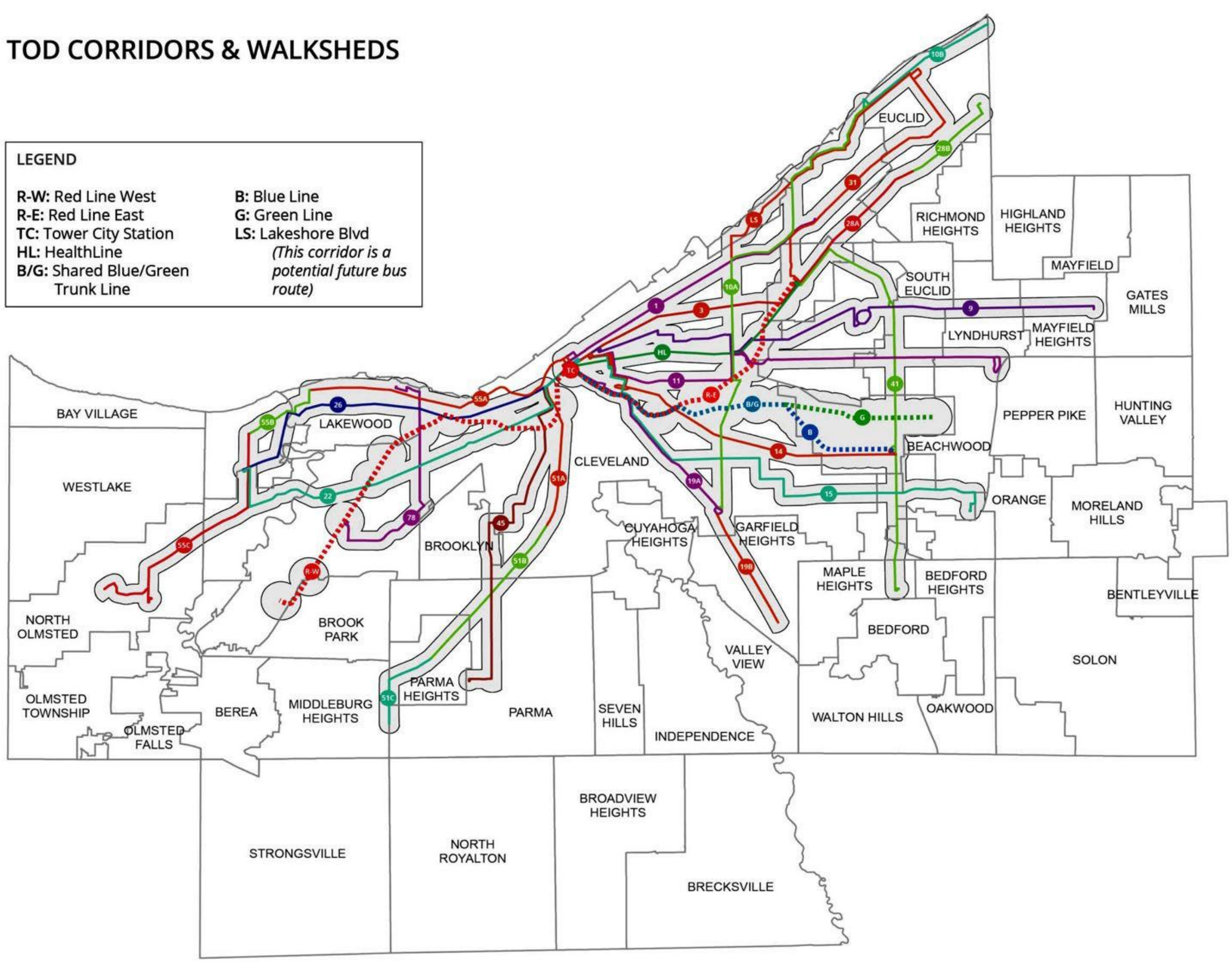
7.5.4.5. Transit-Oriented Development (TOD) Opportunities

TOD is an effective approach to reduce VMT and enhance quality of life and economic vitality. The Cleveland-Elyria MSA, with its existing transit infrastructure and diverse community typologies, has opportunities for TOD strategies tailored to local contexts. The region's well-established development patterns will not change quickly, but the following approaches occur over time.

Corridor-Based Development: Development along key transit corridors will connect major employment centers, educational institutions, and cultural destinations. These corridors include existing rail and BRT lines and potential future bus routes with frequent service (<30 minutes headways). Targeted zoning updates will be essential to focus development around rail stations and major bus stops, while they maintain compatibility with surrounding neighborhoods.

In 2017, GCRTA created general guidelines for TOD developments, including technical recommendations for communities based on the density, appropriate land use mix, orientation, and overall connectivity. In 2017, NOACA completed a TOD Scorecard and Implementation Plan. The Cuyahoga County Planning Commission (CCPC) built on this work through a four-part TOD Study, including a Model TOD Zoning Overlay and priority TOD corridors (**Figure 35**).[295] Collectively, these studies, plans, and tools lay a solid foundation for TOD projects in Cuyahoga County and across the MSA.

Figure 35: Cuyahoga County TOD Corridors



Cross-Jurisdictional Coordination: Many transit corridors cross municipal boundaries, which creates both challenges and opportunities for coordinated development. The region should expand upon existing policies for multiple jurisdictions to collaborate on planning efforts and equitably share tax benefits from TOD. This might include tax-base sharing agreements, joint development authorities, and regional infrastructure investment programs to ensure all communities benefit from transit-oriented growth.

First/Last Mile Solutions: Even the best transit systems reach only a portion of potential riders directly. Comprehensive first/last mile solutions—including mobility hubs with micro-mobility options, enhanced pedestrian infrastructure, and neighborhood shuttles—can significantly extend the effective reach of major transit lines. These connections multiply the impact of transit investments and make car-free or car-light lifestyles viable for more residents. Nevertheless, some of these solutions, such as micro-transit and neighborhood shuttles, may not always be cost-effective options.

Anchor Institution/Major Employer Partnerships: The Cleveland-Elyria MSA benefits from numerous major institutions, including world-class universities, healthcare systems, cultural organizations, and large employers. Partnership with these anchor institutions in TOD implementation would accelerate progress significantly. These partnerships, which already exist in University Circle and are replicable in other parts of the region, include employer-assisted housing programs (such as down payment assistance), transit pass subsidies, shared parking arrangements, or coordinated development initiatives that connect institutional campuses with surrounding neighborhoods via transit.

Near-Term TOD Strategies (2025-2030): In the near term, the region can focus on existing transit assets and preparation for future expansion:

- Public land inventory and strategic disposition: Identify priority parcels (including publicly owned and landbank) within a half mile of high-capacity transit stations and develop strategic disposition plans that prioritize affordable housing, mixed-use development, and job creation.
- TOD overlay districts: Establish TOD overlay districts in key station areas that reduce parking requirements, streamline approval processes for projects that meet TOD criteria, and incentivize affordable housing inclusion. The CCPC Model Zoning Overlay represents an important resource for communities throughout the MSA.[296]
- Anchor institution housing initiatives: Use the established Greater Circle Living Initiative in University Circle as a model to partner with major employers along transit corridors.[297] Develop employer-assisted housing programs that encourage employees to live near transit and reduce commute distances.
- Station area planning: Continue and accelerate the creation of comprehensive station area plans for all rapid transit stations that identify development opportunities, necessary infrastructure improvements, and implementation strategies, in coordination with cities and transit authorities.
- Tax increment financing (TIF) districts: Establish TIF districts around key transit stations to capture value and reinvest in infrastructure improvements that support walkability and

development. Cuyahoga County's TOD Loan Program also provides an important funding mechanism for TOD projects and could be a model for other counties.[298]

Mid-Term TOD Strategies (2030-2040): As initial TOD nodes mature and transit service expands, mid-term strategies should focus on stronger connections between nodes and TOD expansion into more communities:

- Transit-supportive parking reform: Implement comprehensive parking reforms region-wide, including maximum parking requirements in transit-rich areas, shared parking arrangements, and parking benefit districts that fund local improvements.
- Transit corridor housing funds: Establish dedicated funding mechanisms to support affordable housing development and preservation within transit corridors, potentially through linkage fees on commercial development or bond measures.
- Joint development programs: Create formal joint development programs between transit agencies and municipalities that leverage transit-owned properties for mixed-use, mixed-income development.
- BRT corridor intensification: As BRT expands throughout the region, proactively rezone corridors to accommodate transit-supportive densities before land values increase.
- Regional TOD certification program: Develop a certification process for TOD projects that meet specified criteria for density, affordability, and design, with certified projects eligible for expedited permitting, fee waivers, and other incentives.[299]
- Mobility hubs: Implement comprehensive mobility hubs at key transit stations that integrate various transportation modes (transit, bike share, car share, scooters, etc.) with community amenities and services.

Long-Term TOD Strategies (2040-2050): Long-term strategies should focus on systems transformation and truly transit-oriented community creation throughout the region:

- Regional value capture system: Establish a regional value capture system that redirects a portion of development value created by transit investments toward affordable housing, public space improvements, and transit service enhancements.
- Transition of auto-oriented corridors: Transform aging auto-oriented commercial corridors into mixed-use transit corridors through comprehensive redevelopment strategies, potentially including the conversion of excess roadway capacity to transit lanes and linear parks. These efforts would require significant funding and support from the surrounding communities.
- Parking conversion program: Implement a formal program to convert underutilized parking structures and lots in transit-rich areas to housing, public space, and community uses as parking demand decreases.
- Network of 15-minute neighborhoods: Build upon successful TOD nodes to create an interconnected network of "15-minute neighborhoods" where residents can access daily needs within a short walk or bike ride.
- Automated transit feeder network: Deploy automated shuttle services as feeders to high-capacity transit lines to significantly expand the reach of the transit system.

Special District Implementation Tools: Successfully TOD implementation at scale may require specialized governance and financing tools that transcend traditional municipal boundaries:

- Transit Benefits Districts: Create special assessment districts (similar to special improvement districts) around transit stations where property owners contribute to station area improvements and operations that benefit their properties.
- TOD Classification in Land Banks: Establish divisions within existing land banks focused on transit corridors that can assemble and hold properties for future transit-supportive development.
- Cross-jurisdictional Tax Sharing: Implement tax base sharing agreements between municipalities along transit corridors to ensure the benefits of station area development are distributed equitably.
- Infrastructure Finance Districts: Form special districts that can issue bonds against future tax revenue to fund the upfront infrastructure costs necessary to support higher-density development around transit.
- Regional TOD Fund: Create a dedicated regional fund that provides favorable financing for mixed-income housing and mixed-use development within transit corridors. Cuyahoga County's TOD Loan Program represents a first step towards such a fund.

Implementation of these strategies over time and adaptation to the unique characteristics of different communities throughout the MSA can make TOD a powerful tool for VMT reduction and create more vibrant, equitable, and sustainable communities.

7.5.5. Transportation & Mobile Sources Sector Benefits & Co-Benefits

Emissions reductions in the transportation sector are primarily driven by the full-scale adoption of cleaner vehicles and fuels for on-road use. In the optimal implementation scenario, the electrification of rail and non-road vehicles reduces emissions from those segments to zero, while the use of sustainable fuels in marine and aviation applications cuts emissions by up to 95% for those modes.

7.5.5.1. GHG Emissions Reductions from Transportation & Mobile Sources

Table 28 breaks down GHG reductions by segment for this sector.

Table 28: GHG Reductions from Transportation & Mobile Sources Measures by Segment

Segment	2050 BAU Emissions ($MMTCO_2e$)	2050 Reduction Measures Emissions ($MMTCO_2e$)	Emissions Reductions (%)
On-road Gasoline Vehicles	3.90	0.04	99%
On-road Diesel Vehicles	1.29	0.01	99%
Aviation	0.42	0.02	95%
Maritime	0.21	0.01	95%
Rail	0.16	0	100%
Non-road Vehicles	0.08	0	100%
Total	**6.06**	**0.08**	**99%**

7.5.5.2. Co-Benefits from Transportation & Mobile Source Measures

Air Quality Co-Benefits: One of the primary co-benefits of transportation decarbonization strategies is the associated reduction in harmful air pollutants. Decreases in $PM_{2.5}$, SO_2, NO_x, and VOCs can provide significant public health benefits. **Table 29** breaks down the air quality benefits from emissions reduction measures in this sector. This analysis assumes that 99% of on-road vehicles are electric and VMT declines 30% by 2050, relative to the BAU case.

Table 29: Air Quality Co-Benefits Transportation & Mobile Source Sector Measures

Segment	Reduction in SO_2 (Tons)	Reduction in NO_x (Tons)	Reduction in VOCs (Tons)	Reduction in $PM_{2.5}$ (Tons)	Annual Avoided Health Costs
On-road Vehicles	39.2	1,183.8	48.2	7.2	$30.7 million
Aviation, Maritime, & Rail	33.1	2,093.3	83.2	50.5	$77.2 million
Non-road Vehicles	1.0	99.1	7.2	1.2	$2.8 million
Total	**73.3**	**3,376.2**	**138.6**	**58.9**	**$110.7 million**

Traffic Safety Co-Benefits: Traffic crashes are a leading cause of death and injury throughout the Cleveland-Elyria MSA. From 2020-2024, there were 812 traffic fatalities across the MSA, an average of 162 per year.[300] The largest share of these fatalities occurs in Cuyahoga County (64%). Since 2020, the number and rate of fatal traffic crashes have increased in the Cleveland-Elyria MSA, reflecting a national trend. In 2014, Ohio experienced 0.89 fatalities per hundred million vehicle miles travelled (HMVMT); by 2022, this rate increased by 28% to 1.14.[301]

Meeting the CCAP target of reducing VMT by 15% through 2030 and 30% by 2050 will significantly reduce the number of people injured and killed on the region's roads. To assess these benefits, staff compared projected VMT from 2025-2050 under a BAU scenario and under a scenario in which VMT decreased in a linear fashion to meet the CCAP targets. This analysis assumes that fatality and serious injury rates per HMVMT will remain at 2022 levels, which were 1.144 and 6.703, respectively. For a more detailed methodology, refer to Appendix A.

Results from this analysis appear in **Table 30**. From 2025-2050, the Cleveland-Elyria MSA would avoid a total of 7,371 serious injuries and 1,258 fatalities from traffic crashes due to reduced VMT. More information on the benefits from these reduced crashes, along with potential disbenefits from increased cyclist and pedestrian crashes, appears in Chapter 8.

Table 30: Traffic Safety Co-Benefits from VMT Reduction in Cleveland-Elyria MSA

County	Annual Traffic Fatalities Avoided (2030)	Annual Traffic Fatalities Avoided (2050)	Cumulative Traffic Fatalities Avoided (2025-2050)	Annual Serious Injuries Avoided (2030)	Annual Serious Injuries Avoided (2050)	Cumulative Serious Injuries Avoided (2025-2050
Cuyahoga	24	26	685	143	154	4,016
Geauga	2	4	74	13	24	435
Lake	4	5	132	26	30	775
Lorain	6	10	207	36	60	1,212
Medina	5	8	159	28	45	933
MSA Total	**42**	**53**	**1,258**	**246**	**313**	**7,371**

Physical Activity Co-Benefits: Increasing the share of residents who bike and walk for transportation will also provide significant co-benefits from physical activity. Research demonstrates the widespread public health benefits of active transportation, including reducing the risk of premature mortality, cardiovascular disease, type 2 diabetes, and cancer-related mortality.[302] Enabling more residents to access safe infrastructure for active transportation will be vital in a region where nearly one-quarter of adults (23.6%) reported getting no leisure-time physical activity during 2024.[303]

Reducing VMT by 15% through 2030 and 30% by 2050 will significantly increase the share of residents engaging in physical activity across the MSA. To assess these benefits, staff assumed that the share of VMT reduced through 2030 and 2050 will shift to other travel modes in proportion to their commute mode share during 2022.[304] This analysis used per person mile estimates of physical activity from walking and biking from the Transportation and Climate Initiative (TCI), which are based on the World Health Organization's (WHO) Health Economic Assessment Tool (HEAT) for walking and cycling. For a more detailed methodology, refer to Appendix A.

Table 31 displays the results of this analysis. As the data demonstrate, the co-benefits from increased physical activity are comparable to the annual benefits from improved air quality from all CCAP measures. Yet, these numbers may underestimate the potential benefits. This analysis assumes, for instance, that just 1.3% of the avoided VMT shifts to cycling; other analyses suggest that biking could account for 10% or more of VMT reduction.[305] Additionally, this analysis does not account for the physical activity benefits of increased public transit use. Research demonstrates that public transit users get more physical activity than other travelers, as they frequently walk or bike to and from their transit stops.[306] Information on the economic benefits of physical activity appears in Section 8.2.

Table 31: Physical Activity Co-Benefits from VMT Reduction in Cleveland-Elyria MSA

County	Annual Premature Deaths Avoided (2030)	Annual Premature Deaths Avoided (2050)	Cumulative Premature Deaths Avoided (2025-2050
Cuyahoga	256	275	7,190
Geauga	15	28	502
Lake	34	40	1,028
Lorain	61	102	2,056
Medina	23	37	765
MSA Total	**389**	**482**	**11,541**

Noise Reduction Co-Benefits: EVs offer important co-benefits in the form of reduced traffic noise, particularly in urban and residential environments. Unlike internal combustion engine vehicles, EVs produce significantly less propulsion noise at lower speeds, where engine noise typically dominates over tire and wind noise. Studies have shown that EVs can reduce average pass-by noise by 4–5 decibels in city conditions compared to conventional vehicles.[307] This noise reduction contributes to improved quality of life and public health outcomes, as chronic exposure to transportation noise has been linked to cardiovascular disease, sleep disturbance, and impaired cognitive development in children.[308] The electrification of vehicle fleets—especially for transit, delivery, and municipal use—can help reduce these risks while it also enhances the livability and accessibility of public spaces.

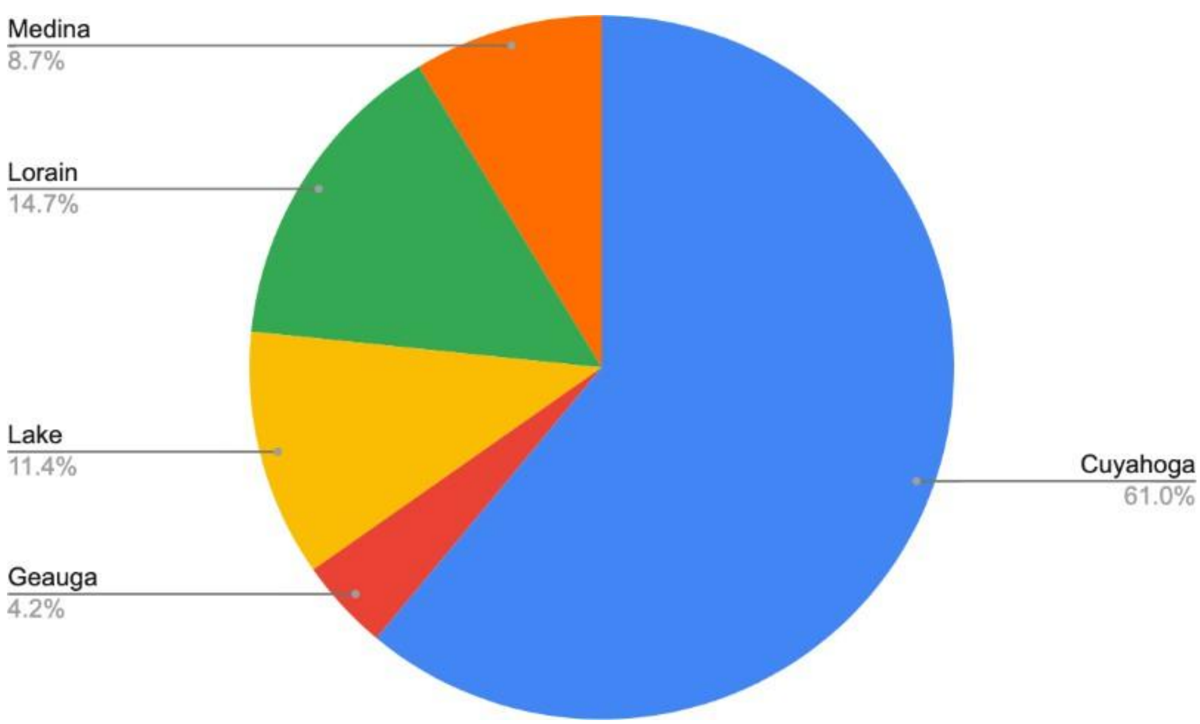
7.6. Waste & Material Management Sector

Reaching net zero emissions in the Waste and Material Management Sector is important for attaining the Cleveland-Elyria MSA's emissions targets. The sector accounts for 9.5% of total GHGs in the MSA, with 5% from solid waste, 4% from HFCs (refrigerants), and 0.5% from water and wastewater. This section describes actionable strategies and policies.

7.6.1. MSA Context

While Waste and Material Management emissions are found in each of the five counties, the distribution of those emissions is not equal for each county. **Figure 36** shows the total industrial emissions in each of the five counties during 2022. Cuyahoga County is responsible for 61% of emissions from this sector, as it generates significantly more waste than any of the other counties and houses 19 landfills compared to one in Geauga County, one in Lake County, four in Lorain County, and two in Medina County.

Figure 36: Waste & Material Management Sector GHG Emissions by County (2022)



7.6.2. Challenges & Barriers to Decarbonization

The largest challenge is that emissions are largely due to the biological processes associated with the breakdown of waste in a landfill or wastewater treatment facility.[309] These process emissions are only avoidable through waste reduction, so solutions require process emissions capture. Capture systems can have high upfront capital costs. The solutions to replace refrigerants with climate-friendly alternatives and create programs to properly dispose of equipment that uses HFC at end-of-life require investments in training, education, and infrastructure.[310]

7.6.3. Local Success Stories & Opportunities

The treatment and disposal of industrial waste byproducts are a crucial part of environmental health. Several waste management facilities in Northeast Ohio have implemented measures to treat waste in a manner consistent with ambitious sustainability goals. The Northeast Ohio Regional Sewer District (NEORSD) introduced three new fluidized-bed incinerators that are top-of-the-line when it comes to sustainability. They conserve natural gas and reduce GHG emissions. Renewable-energy upgrades at each facility capture waste heat to spin turbines that generate 25% of each facility's electrical needs. The project saves NEORSD $1-2 million per year in electrical costs and cuts natural gas consumption by 95%. This improved treatment of biosolid waste from the wastewater treatment process not only handles waste more conscientiously but also implements sustainability measures that generate power.[311]

EDL is the owner and operator of the Lorain Renewable Natural Gas (RNG) facility. Lorain RNG works with the Republic Services Lorain County Landfill in Oberlin to convert waste gases from the landfill into a cleaner source of fuel for the power utility industry and light commercial vehicles. Lorain RNG has the capacity to convert methane-rich gas from landfill into approximately 1.6 MMBtu per year of pipeline-quality RNG. This saves the equivalent of about 5.5 million gallons of diesel per year when used in vehicle transport. This facility, the first of its kind in Oberlin, provides insight into the kind of waste disposal strategies that also provide sustainable benefits for industry and communities.[312]

7.6.4. Waste & Material Management Sector Emissions Reduction Measures

The following sections describe a full suite of emissions reduction measures from across this sector, which will enable the Cleveland-Elyria MSA to make immediate and sustained progress towards its near- and long-term GHG reduction targets. These measures correspond to the Refrigerants Capture and Solid Waste Diversion measures from the PCAP; however, this section provides a fuller suite of measures that will decarbonize this sector over the long-term. Solid waste and refrigerants generate 96% of GHGs from this sector; however, the CCAP adds measures that focus on the remaining 4% of emissions from Water and Wastewater. Emissions reduction measures for this sector include Electrification, New Industry Support, Alternative Fuels, Energy Efficiency, Process and Material Efficiency, Renewable Energy, and CCUS.

7.6.4.1. Solid Waste

Solid waste is any garbage, sludge, or other discarded material that results from industrial, commercial, agricultural, or community activities. Solid waste is not limited to physically solid waste; it often takes the form of liquid, semi-solid, or contained gaseous material. Most human activities result in some solid waste production.[313] Solid waste management includes handling municipal solid waste, and hazardous waste. The sector includes landfills, recycling facilities, waste-to-energy plants, and hazardous waste treatment centers. Emissions in this industry come from landfill methane (chemical reactions), fossil fuel-powered collection and processing equipment (onsite transportation), and incineration (onsite energy generation).[314] Methods for decarbonization of Solid Waste are Electrification, New Industry Support, and Alternative Fuels.

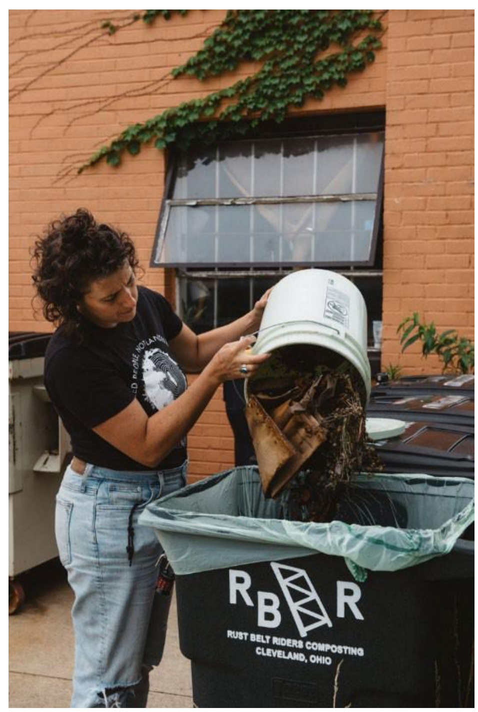
Electrification: There are several opportunities to electrify aspects of solid waste management. Currently, compactors, sorters, and transport equipment are diesel-powered, so electrification would reduce emissions up to 60%, reduce noise, and directly improve air quality.[315] Additionally, some landfills have onsite propane heating that contributes to their emissions.[316]

Alternative Fuels: Garbage collection fleets currently run on diesel. Change to BEV or hydrogen FCVs reduces emissions from waste transport 80-90% and improves worker health.[317]

New Industry Support: Many recyclable materials are still landfilled due to lack of processing infrastructure. Ideally, waste materials would be fully reused, recycled, or converted to energy in a zero-waste economy.[318] This would minimize not only landfill dependence but also raw mineral extraction. An increase in recycling industries and novel recycling techniques that can utilize more landfilled items would reduce landfill and manufacturing emissions because of reduced demand for raw materials.[319]

Currently, many landfills flare or vent their landfill gas, which wastes potential energy and emits methane. Instead, landfill gas capture to produce renewable natural gas can reduce landfill emissions 35-90% and provide a renewable source of energy that can be sold to natural gas suppliers or used in waste-to-energy plants with a CCUS system.[320] West Lorain Landfill in Lorain County partnered with EDL energy to develop a renewable natural gas facility that became operational in November 2024.[321]

Additionally, 24% of municipal solid waste comes from food waste, and it reduces the methane released by landfills and, in turn, the total emissions, by 58%.[322] Organizations such as Rust Belt Riders help divert food waste from landfills and there are many other opportunities for communities and businesses to participate in this practice.[323] Community composting programs, local agreements with restaurants, and a system to promote composting in public parts and at public events are strategies to reducing this waste stream further.



Source: Rust Belt Riders

7.6.4.2. Water and Wastewater

Water and wastewater treatment centers generate emissions from energy consumption, biological processes, and the incineration of waste. NEORSD's Southerly Wastewater Treatment Center and

Lakewood Wastewater Treatment Center in Cuyahoga County are two examples of different strategies to utilize waste for energy. Southerly installed fluidized-bed incinerators that burn biosolids to generate heat and energy to produce 25% of the electricity needed for the rest of the plant and reduce their emissions by 80%.[324] Lakewood Wastewater Treatment Center has anaerobic digesters that produce biogas, which they then burn to produce 100kW of electricity.[325] In addition, the Kenneth W. Hotz Water Reclamation Facility in Medina County implemented a design-build performance contract to make improvements to their facility and use savings from increased efficiency to pay for future improvements.[326] These shifts are the most important changes in which other wastewater treatment centers should invest for emissions reductions.

Subsector decarbonization methods include Energy Efficiency, Process and Material Efficiency, Renewable Energy, Alternative Fuels, and CCUS.

Energy Efficiency: There are many opportunities to reduce energy consumption within water and wastewater treatment facilities. Optimize pumps, motors, and other electro-mechanical devices through settings adjustments, investments in variable motor drivers, or automation additions to vary motor speeds based on demand will reduce overall power consumption.[327] Aeration is a critical step in wastewater treatment as it supports microbial decomposition, prevents odors, removes ammonia, and keeps solids suspended. Replacement of traditional blowers with magnetic suspension blowers improves aeration efficiency and reduces energy use by 20-30%.[328] The digestion and incineration processes generate heat and use of this thermal energy with CHP systems after the process can save 20% energy.[329]

Process and Material Efficiency: Anaerobic digestion breaks down organic materials without oxygen, leading to fermentation that produces biogas. If fat is co-digested with sewage in anaerobic digestion, it could double energy production.[330]

Renewable Energy: Southerly, Lakewood, Medina County, and many other facilities in the region have infrastructure to capture and combust gas. A relevant CHP system at other locations could not only significantly reduce the emissions of the facility but also generate significant amounts of energy for the facility and the broader community. Fluidized bed incinerators burn biosolids in a hotbed of sand. The recovered heat can generate energy or warmth.[331] These incinerators are less expensive to install than anaerobic digesters, produce less waste after combustion, and are better for human health.[332] Anaerobic digesters have microorganisms that break down organic material, and, through a fermentation process, produce biogas that generates heat and power. Though they take up more space, anaerobic digesters are more efficient in energy recovery and have a smaller environmental impact than fluidized bed incinerators.[333] Wastewater treatment facility operators can choose the approach that best meets their needs, resources, and goals.

Alternative Fuels: Currently, natural gas in fluidized bed incinerators maintains an optimal combustion environment. Replacement with hydrogen or biogas for auxiliary fuel in fluidized incinerators would eliminate emissions from combusting natural gas.[334]

CCUS: Regardless of auxiliary fuel use, fluidized bed incinerators are still a combustion process that breaks down organic matter and, therefore, emits CO_2. A carbon adsorption bed in incinerators could capture up to 88% of CO_2 emissions.[335]

7.6.4.3. HFCs (Refrigerants)

HFCs are refrigerants used in refrigeration and cooling. They are primarily used in air conditioning and, to a lesser extent, medical equipment. Cooling is highly energy intensive; it accounts for 10% of all global electricity consumption. Additionally, HFCs are much more potent than CO_2, some with GWPs well over 1,000.[336] Methods to decarbonize this subsector are Energy Efficiency, Alternative Fuels, and Process and Material Efficiency.

Energy Efficiency: Natural cooling methods like green or white roofs, insulation, night cooling, shade, and reduced operating temperatures can lower demand for HFCs and thus decrease emissions. If all stationary air conditioning were replaced with the highest-efficiency refrigerants, an estimated 40% efficiency improvement would occur by 2030.[337] Leak prevention would also improve energy efficiency and reduce HFC emissions.

Alternative Fuels: Natural refrigerants like CO_2, hydrocarbons, and ammonia are sustainable HFC alternatives. These natural refrigerants have low GWPs, and their use could decrease consumption of energy, gas, and water and reduce GHGs.[338]

Process and Material Efficiency: Roughly 90% of GHGs from refrigerants are the result of leaking at the end of a refrigerant's life cycle. People could bring machines that use refrigerants, like AC units and refrigerators, to refrigerant management facilities at the end of their useful lifetimes for refrigerant destruction and emissions prevention. Just one year of proper handling of end-of-life refrigerants through destruction and recycling may save up to 2,990 $MMTCO_2e$.[339]

7.6.5. Benefits & Co-Benefits from Waste & Material Management Measures

Waste and Material Management sector decarbonization reduces harmful co-pollutants in the region. U.S. EPA's COBRA tool quantifies the health benefits from emissions reductions through solid waste and water and wastewater treatment (see **Table 32**); HFCs do not directly produce the harmful co-pollutants evaluated with the COBRA tool.

Table 32: Air Quality Co-Benefits from Waste & Material Management Sector Measures

Subsector	Reduction in SO_2 (Tons)	Reduction in NO_x (Tons)	Reduction in VOCs (Tons)	Reduction in $PM_{2.5}$ (Tons)	Avoided Health Costs
Solid Waste	19.3	272	42.4	40.8	$17.4 million
Water & Wastewater	7.61	29.1	1.4	5.27	$2.1 million
Total	**27**	**301**	**44**	**46**	**$19.5 million**

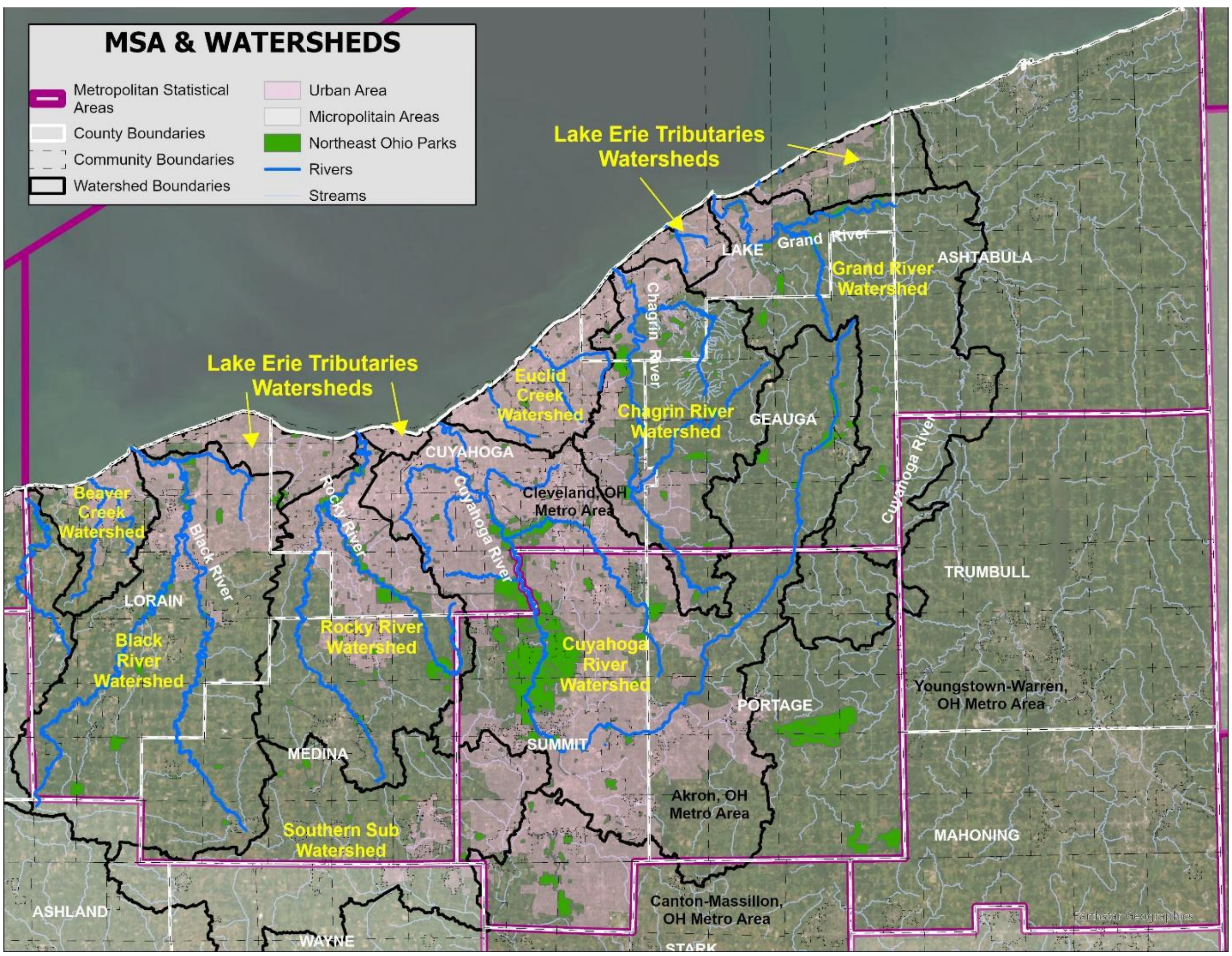
7.7. Agriculture, Forestry, and Other Land Uses (AFOLU) Sector

The Cleveland-Elyria MSA can reduce net GHG emissions through strategic reforestation, wetland restoration, and innovative zoning practices. While land-based measures would offset only about 1% of current regional emissions, their substantial co-benefits make them valuable components of regional decarbonization.

7.7.1. MSA Context

Figure 37 displays the major watersheds and parklands within the Cleveland-Elyria MSA> Nature-based solutions are a largely untapped tool to reduce GHGs and enhance resilience within the MSA. Cleveland's tree canopy has declined from 37% in 1950 to 18% today, while the five-county region averages 30%.[340]

Figure 37: Watersheds & Major Parklands in the Cleveland-Elyria MSA



Strategic reforestation in underutilized areas would create carbon sinks and improve air quality; support wildlife habitats; and enhance recreation. Restoration of previously drained wetlands would also provide carbon storage, flood control, and water purification benefits. These projects also offer public education opportunities.

Zoning can incentivize carbon-negative land use through economic and regulatory advantages for landowners who prioritize sequestration. County planning commissions across the MSA can develop model ordinances that reflect regional differences. Implementation faces challenges in rural townships where property rights concerns are paramount, but even partial adoption could yield significant cumulative reductions.

The MSA's industrial legacy, Lake Erie coastal wetlands, and a mix of working farms and second-growth forests create both GHG sources (through soil disturbance and fertilizer use) and powerful sinks. With over 90% of Ohio's original wetlands lost and thousands of acres of marginal farmland poised for forest succession, strategic land management presents significant opportunities for climate mitigation and adaptation. Although even full deployment of land-based measures would offset only about 1% of current regional emissions, their co-benefits make them valuable in a regional decarbonization strategy.

7.7.2. Challenges & Barriers to Decarbonization

The AFOLU sector constitutes a small part of regional emissions, with agricultural emissions estimated at 0.8% of total emissions and forests offsetting 4% of total emissions in 2022. AFOLU sector measures will not have a big impact on regional decarbonization. However, they remain an important part of any comprehensive decarbonization plan.

Urban tree initiatives in the Cleveland-Elyria MSA must contend with a persistent set of negative perceptions. Residents worry about falling limbs, clogged gutters, buckled sidewalks, and the cost of future maintenance - concerns that are amplified in low-income neighborhoods where municipal crews have struggled to keep up with maintenance needs. Private homeowners sometimes see large shade trees as liabilities rather than assets, especially with regards to utilities or insurance premiums. These negative perceptions make it harder to build momentum with large-scale tree canopy expansion in urban settings.

Wetland restoration faces an image problem. A common misconception around the US is that wetlands increase mosquitos, despite research that shows well-designed stormwater or coastal wetlands can maintain mosquito densities no higher (and sometimes lower) than conventional detention basins.[341] Others equate wetlands with lost developable real estate or diminished tax revenue, especially in suburbs where buildable land is scarce. Overcoming these objections often requires up-front education on modern wetland mosquito management techniques and clear demonstrations of the flood-loss avoidance and water quality savings that wetlands deliver. Additionally, it may be valuable to demonstrate to some communities that wetland conservation and restoration can increase property values for nearby property owners.[342]

Risk management and cash flow realities hampers the shift to conservation agriculture. There must be clear financial benefits to adopt no- or low-till agriculture or plant cover crops. In many cases, these are not very apparent due to low adoption rates. Growers hesitate to use practices their closest neighbors have not yet proven and they are wary of mandates that might erode autonomy over land management decisions.

More than a hundred municipalities and numerous rural townships in the MSA hold their own zoning authority, so code alignment across the MSA is inherently difficult.[343] Property-rights sensitivity, especially in un-zoned townships, limit mandatory approaches. Meanwhile, Cleveland continues to lose roughly 97 acres of tree canopy each year, hindered by maintenance backlogs and conflicts with overhead utilities. Verification and finance remain obstacles: few standardized carbon accounting tools exist for small, local projects, and revenue from voluntary offset markets is uncertain. Brownfield sites present a further tradeoff, because utility-scale solar usually delivers larger near-term CO_2 reductions per acre than regreening, even though green space yields long-term ecosystem services. Planners must balance economic development, scientifically rigorous carbon accounting, and practical implementation while they ensure benefits reach low-income, disadvantaged, and climate-vulnerable communities.

7.7.3. Local Success Stories & Opportunities

Several initiatives from the region already demonstrate what is possible. The Cleveland Tree Coalition (CTC) and the Western Reserve Land Conservancy (WRLC) coordinate efforts to increase the City of Cleveland's tree canopy back to 30% by 2040, with a focus on vacant lots and infill strips that provide both social and climate benefits. Great Lakes Restoration Initiative (GLRI) projects at Mentor Marsh, Sandusky Bay, and along the lower Cuyahoga River have re-established coastal wetlands.[344] Parma, with the NEORSD, has purchased flood-prone homes on Pleasant Valley Road and restored the natural floodplain to reduce flood risk and create new carbon sinks.[345] In 2024 the Lorain County Regional Planning Commission, with USDA support, completed a no-till suitability analysis to guide soil carbon programs across agricultural lands.[346] Finally, the five county planning commissions have undertaken model zoning ordinances that integrate carbon capture incentives into suburban growth areas and rural conservation districts - tools other local governments can adopt.

7.7.4. AFOLU Sector Emissions Reduction Measures

The following sections describe a full suite of emissions reduction measures from across the AFOLU sector, which will support immediate and sustained progress in the Cleveland-Elyria MSA toward GHG reduction targets. These measures largely correspond to the Nature Based Solutions and Agricultural Actions measures from the PCAP; however, this section provides a fuller suite of measures that will decarbonize this sector over the long-term. While on-road vehicles account for 90% of GHGs from this sector, the MSA must have a strategy to eliminate the remaining 10% of emissions. CCAP includes measures to remove emissions from this sector and enhance natural emissions sinks.

7.7.4.1. Natural Ecosystem Restoration

Wetland and Riparian Restoration: Communities throughout the watershed could prioritize wetland and riparian zone restoration, particularly in flood-prone areas where these natural systems provide multiple benefits. Restored wetlands sequester significant carbon in both vegetation and soils while they filter pollutants and regulate water flows. The City of Parma already implements this approach, as noted. Communities can focus on protecting and enhancing Lake Erie's coastal marshes, stopover habitats, and river corridors, which are critical for biodiversity and climate resilience.

Wetlands are among the most effective natural systems for long-term carbon sequestration, especially due to their waterlogged, anoxic conditions that slow decomposition and promote the buildup of organic matter. Studies in Ohio and across North America show that both natural and created wetlands capture significant amounts of carbon annually, up to 267 grams of carbon per square meter, per year, ($g/C/m^2/year$) in some constructed sites, often exceeding the rates observed in nearby natural wetlands.[347] Peatlands, in particular, have stored carbon for millennia in deep organic soils, forming one of the largest terrestrial carbon pools.

Although wetlands emit CH_4, especially in tropical or impounded freshwater systems, many restored and temperate wetlands remain net carbon sinks over time. In Ohio, the CH_4 emitted was 1/50 the CO_2 sequestered. Because this is well above the GWP adjustment of 25:1, these ecosystems still provide a net climate benefit.[348] Factors like vegetation density, water depth, salinity, and soil iron content all influence methane flux; saline and iron-rich systems generally suppress CH_4 emissions. Carbon sequestration rates tend to peak 10 to 15 years after wetland creation, and although they may decline slightly over time, they remain significant for decades, particularly in deep, vegetated, and flow-connected wetland zones.[349]

Wetlands also intersect with green infrastructure and energy strategies. Constructed wetlands used for wastewater or stormwater treatment can serve dual roles: they capture carbon and also produce biogas through anaerobic digestion. This biogas, if properly refined, can be a renewable energy source injected into natural gas pipelines or used on-site to offset energy demand. Currently, fewer than 10% of U.S. wastewater treatment plants currently use biogas beneficially. However, the potential for expansion is high, especially in cities where biogas production can align with zero-waste and climate goals.[350] Constructed wetlands are generally less energy-intensive than traditional treatment systems. If designed carefully, they can match or exceed natural wetlands in carbon sequestration performance while they also manage water quality, sedimentation, and biodiversity.

The economics of wetland restoration are highly variable but can be offset through carbon credits, mitigation banking, and avoided infrastructure costs. Restoration costs range from $15,000 to over $80,000 per acre depending on complexity, hydrologic modifications, and intended use. Despite these costs, restored wetlands can yield substantial long-term benefits, including up to 6 milligrams of carbon per hectare, per year (Mg C/ha/yr) in sequestration, reductions in nutrient runoff, and enhanced flood protection.[351] Carbon markets, such as those run by The Nature Conservancy in Ohio, allow developers to fund large-scale, strategically located wetland projects instead of piecemeal site mitigation. Strategic site selection based on hydric soils, high water tables, and lakebed-derived soil textures can enhance long-term performance. Given that 90% of Ohio's wetlands have been lost or degraded, wetland integration into broader climate and land use planning is a useful strategy for carbon drawdown, ecosystem resilience, and water resource protection.

Prairie and Grassland Restoration: Native prairie and grassland ecosystems, which once covered portions of the region, could be reconstructed in appropriate locations. These ecosystems sequester substantial carbon, primarily in their extensive root systems, while they require minimal maintenance once established.

7.7.4.2. Agricultural Practices

Agricultural decarbonization centers on increased soil organic carbon (SOC), a key atmosphere-to-soil sink that helps mitigate climate change. Practices such as cover cropping, reduced tillage, and organic amendments are central to boost SOC. Meta analyses show that cover cropping can increase near-surface SOC by an average of 15.5%, resulting in average sequestration rates of 0.56 Mg C ha/yr. However, SOC gains are often shallow and may not persist in deeper layers unless paired with practices that promote deeper rooting and sustained organic input. Conservation agriculture (CA), which combines minimal soil disturbance, continuous organic cover, and crop diversification, has emerged as a comprehensive system. CA improves soil structure; reduces erosion; and enhances water retention, while it contributes to SOC accumulation over time.

Despite the promise of no-till (NT) farming, its effectiveness for long-term SOC sequestration is mixed. No-till farming improves soil aggregation and reduces erosion, which can reduce the risk of harmful algal blooms. Studies also show that it can increase SOC near the surface; however, it can often cause SOC losses in deeper soil layers, as tillage introduces crop residues into the soil, which restores carbon in deeper soil layers.[352] Total SOC gains under NT are often negligible unless combined with other strategies such as cover cropping, organic amendments, or diverse crop rotations. In some cases, no-till may even reduce carbon stocks if yields decline and residue inputs fall below critical thresholds. Thus, NT is most effective when integrated into broader conservation systems that maintain or increase carbon inputs, such as rotational grazing, agroforestry, or double cropping systems that extend vegetative cover and organic input throughout the year.

Beyond carbon, conservation agriculture delivers multiple co-benefits critical to sustainability and climate resilience. Cover crops, for example, regulate soil temperature, suppress weeds, and reduce nitrogen leaching and nitrous oxide emissions. Residue retention enhances infiltration and water holding capacity, especially on sloped or rain-fed lands. CA systems have been shown to reduce surface runoff and erosion by up to 80% compared to conventional practices. Agroforestry, which blends trees into croplands, stores carbon above and below ground while it improves biodiversity and stabilizes yields. While conservation systems may require several years to fully deliver soil health gains, their cumulative impact on SOC, GHG mitigation, and climate adaptation makes them tools for decarbonizing agriculture and safeguarding food systems in a changing climate. These practices have relatively limited decarbonization potential at the regional level, but they can be locally important strategies in portions of the MSA with significant agricultural lands (e.g. Geauga County, Medina County).

7.7.4.3. Land Sink Creation and Protection

Expand the Regional Tree Canopy: Once celebrated as the “Forest City,” Cleveland's tree canopy has declined to 18% (2017) through an annual loss of 97 acres. Without intervention, cover will drop to 14% by 2040. The city's 30% canopy goal requires 28,000 new trees annually. Organizations like CTC, WRLC, and municipal partners facilitate regional expansion and merit continued investment.[353]

Although reforestation can only account for a modest amount of regional decarbonization (a 5% canopy increase across five counties would sequester 0.16 $MMTCO_2e$ annually, equal to just 0.4% of regional emissions), communities with less carbon-intensive industries, and thus lower emissions, may be able to offset their emissions through reforestation. This is a practical offset in Geauga, Lake, Lorain, and Medina Counties, where larger tracts of land could be reforested with minimal management costs, since these rural forests pose less of a nuisance for streets, buildings, and electrical grids. The co-benefits of these rural forests - particularly surface cooling - are less impactful in rural settings since there is not a large population immediately adjacent to these forests. In the near term, reforestation is the most proven approach to remove CO_2 from the atmosphere; man-made technologies are in development and tested at commercial scale but are not expected to be ready for deployment within the MSA before 2035.

Formerly redlined Census tracts average 4.7°F hotter than well-resourced neighborhoods.[354] Mature trees reduce surface temperatures by 20-45°F on hot afternoons, which saves millions on air conditioning costs - benefits that are least available to low-canopy communities most in need.[355] However, proper maintenance is essential in LIDAC communities to minimize safety risks and avoid property damage costs. Trees deliver $1.50-$3.00 in benefits per dollar invested, and these returns compound as trees mature. Sustained maintenance funds and prioritization of heat-vulnerable, low-canopy neighborhoods where each tree provides outsized returns in cooling, health, carbon reduction, and stormwater management, are necessary to reverse canopy decline.[356]

Brownfield Restoration: The Cleveland-Elyria MSA contains numerous brownfields and underutilized properties that could be transformed into carbon sequestration assets. There should be special zoning categories for these sites, which provide expedited permitting and other incentives for projects that remediate contaminated soils; implement carbon-capturing landscape designs; use regenerative construction techniques; and create multi-functional green spaces. These carbon-focused redevelopment zones could be particularly impactful in legacy industrial areas along the Cuyahoga River, lakefront areas, and in smaller industrial centers in surrounding counties. Local governments could establish performance standards for carbon sequestration as part of brownfield remediation requirements. Such standards will ensure these sites transition from environmental liabilities to climate assets.

The relative decarbonization benefits of brownfield to green space transformation versus solar installations is quantifiable, though with notable differences in impact mechanisms and timescales. Solar development typically delivers greater immediate carbon reduction benefits. Utility-scale solar installations generate approximately 400.5 MWh per acre per year. When solar panels are installed to replace natural gas, an acre of solar panels avoids 147.8 $MTCO_2e$ per acre per year. Green space conversion provides more modest direct carbon sequestration (approximately 0.5-3 $MTCO_2e$ per acre annually) but offers additional benefits: urban cooling effects that reduce energy consumption; manage stormwater; and enhance biodiversity.[357]

Green space and solar development do not have to be mutually exclusive. Solar arrays can offer shade, absorb heat, and provide habitat. The optimal choice depends on specific site characteristics, local climate conditions, and whether immediate carbon reductions or long-term ecosystem services are priority. Although solar panels installed on brownfields help reduce CO_2 emissions, this may change over time. As the region's energy system shifts towards higher levels of renewable energy production, the CO_2 intensity of displaced generation will likely fall. This will reduce the CO_2 emissions reduction impacts of new solar PV generation.

Soil Carbon Enhancement through Biochar Amendments: All communities could implement soil carbon enhancement through biochar. In urban areas, this could involve biochar or compost during construction projects. In agricultural settings, biochar amendments could help build soil carbon. Public landscapes throughout the region could implement soil management practices that prioritize carbon accumulation.

The region could develop integrated approaches to biomass management that maximize carbon sequestration potential while they provide economic benefits. Communities could establish systems for capturing and processing biomass from urban tree trimming, agricultural residues, and landscape maintenance. Rather than treating these materials as waste, they could become valuable inputs for carbon-sequestering products and energy production. Regional biochar production facilities could transform organic waste into stable carbon that remains sequestered for centuries when incorporated into soils. Local governments could establish programs that divert appropriate organic waste streams to biochar production. This would reduce landfill inputs while it creates a valuable soil amendment. These programs could start with woody materials from urban forestry operations and gradually expand to include other suitable feedstocks.

Carbon-Focused Zoning Overlays: The Cleveland-Elyria MSA contains diverse landscapes that range from dense urban centers to agricultural and forest lands. This diversity provides opportunities to leverage zoning and land use policies as powerful tools for carbon sequestration. While traditional decarbonization efforts often focus on emissions reduction, complementary strategies that enhance natural carbon sinks could amplify climate action efforts. The following approaches could enhance carbon sequestration throughout the region.

Special zoning designations could provide additional benefits for carbon-negative land uses throughout the region. Carbon sequestration overlay zones could function as an additional layer of regulation that works alongside existing zoning categories. Local governments could offer density bonuses or reduced permitting costs for developments that preserve existing mature trees, as these established carbon sinks often provide significantly greater sequestration benefits than newly planted saplings. For example, a 30-year-old hardwood tree can sequester approximately 9.8 kg of carbon per year, while a newly planted sapling (1-5 years) sequesters about 0.9 kg per year—roughly a 10-fold difference.[358] Similar incentives could be extended to projects that implement extensive green infrastructure; use carbon-negative building materials such as mass timber or hempcrete; or integrate native landscaping with high carbon sequestration potential.

In the Cleveland-Elyria MSA, these overlay zones could be particularly effective outer suburbs of Medina, Geauga, and Lorain counties, where new construction actively reshapes the landscape. Municipal leaders could require carbon impact assessments as part of development review processes within these overlay zones. These assessments create accountability for carbon outcomes while they still allow flexible approaches to meet sequestration goals.

Agricultural and Rural Land Protections: Agricultural and natural lands represent some of the region's most valuable carbon sinks. Local governments could develop transfer of development rights (TDR) programs that would allow landowners to sell development rights from carbon-rich lands to developers who want to build at higher densities in designated receiving areas. This market-based approach could simultaneously preserve agricultural and forestry lands with high sequestration potential while it directs growth to locations with less carbon impact.

Rural townships could implement agricultural conservation easements, particularly in areas with high-quality soils capable of significant carbon sequestration. Local zoning codes could establish minimum lot size regulations that prevent fragmentation of carbon-rich land to maintain the integrity of these natural systems. Buffer zones around critical carbon sinks like wetlands, forests, and grasslands could provide additional protection for these valuable resources while they mitigate flood risks and protect water quality.

For communities along the region's rural-suburban fringe, these conservation zoning tools could help establish a clear edge to development and reduce pressure on agricultural lands while they create attractive amenities for nearby residents.

Urban and Suburban Landscape Modifications: Urban and suburban areas throughout the MSA could implement zoning requirements that gradually transform developed landscapes into more effective carbon sinks through minimum green space ratios for new developments, particularly in higher-density areas where every square foot of permeable surface area becomes valuable. Zoning codes could require a percentage of native, carbon-sequestering plant species in landscaping. This moves beyond aesthetic considerations to prioritize ecological function.

Stormwater management zones that prioritize nature-based solutions could be in flood-prone areas throughout the region to create multi-functional spaces that capture carbon and manage water. Zoning incentives could encourage the implementation of green roofs, vertical gardens, urban tree canopy expansion, and permeable surface areas across different development contexts. In the MSA's urban core cities of Cleveland and Lorain; inner-ring suburban communities, including East Cleveland, Lakewood, Cleveland Heights, and Euclid; and established towns, such as Elyria, Painesville, and Oberlin; these approaches could be particularly valuable to counteract the urban heat island effect and create more livable neighborhoods. Second-ring suburbs could incorporate these requirements into redevelopment of aging commercial corridors and office parks to transform these spaces into more resilient, carbon-capturing landscapes.

Mixed-Use and Sustainable Development Zones: Comprehensive approaches to carbon-negative development could be encouraged through mixed-use zoning classifications that reward compact, walkable development with reduced parking requirements, on-site renewable energy production, integrated urban agriculture, and carbon-sequestering landscape designs. These zones could combine transportation-oriented development principles with explicit carbon sequestration requirements.

Communities like Mentor, Brunswick, and Avon could integrate these approaches in town centers and commercial corridors, which create nodes of sustainable development that demonstrate carbon capture in the fabric of attractive, economically vibrant places.

7.7.5. Benefits & Co-Benefits from AFOLU Sector Emissions Reduction Measures

7.7.5.1. GHG Emissions Reductions from AFOLU Measures

AFOLU sector measures will yield some decarbonization benefits for the Cleveland-Elyria MSA.

Ecosystem Restoration: Restoring 500 acres of wetlands by 2030 and 2,500 acres by 2050 would provide net emissions reductions of 2,000 and 10,000 $MTCO_2e$, respectively, if each acre can remove four $MTCO_2e$ per year. Restoring prairies, other ecosystems, agricultural lands, and brownfields would lead to greater emissions removals. If restoration enables the removal of one $MTCO_2e$ per acre, per year, then restoring 5,000 acres can reduce emissions by 25,000 $MTCO_2e$ through 2030 and 100,000 $MTCO_2e$ through 2050. In total, ecosystem restoration can offset would constitute 0.3% of total emissions within the MSA.

Agricultural Practices: The 2022 GHG inventory estimates that agriculture constitutes 0.9% of regional emissions (254,470 $MTCO_2e$). Adopting conservation agriculture practices on 500 additional acres each year and assuming an emission factor of a net reduction of 0.5 $MTCO_2e$ per acre, per year would lead to a reduction of approximately 1,250 $MTCO_2e$ by 2030 and 6,250 $MTCO_2e$ by 2050.

Enhancing Carbon Sinks. Reducing the rate of forest canopy loss and moving towards net canopy gain will offset GHG emissions in the MSA. For each 1% of forest cover retained in the region, that is about 13,000 to 39,000 $MTCO_2e$ per year of avoided emissions. Similarly, for each 1% of net gain in forest cover across the MSA, 13,000-39,000 $MTCO_2e$ per year would be offset. Increasing tree canopy by 1.5% through 2030 and 4.1% canopy by 2050, results in a net reduction of 42,990 and 121,154 $MTCO_2e$ per year, respectively. Biochar amendments to 5% of agricultural lands by 2050 produces a reduction of 16,243 $MTCO_2e$ annually.

Table 33 outlines potential emissions reductions from the AFOLU sector. Through 2050, this sector can provide total savings of 263,700 $MTCO_2e$. Cumulative reductions total 10,000 $MTCO_2e$ from wetland restoration, 100,000 $MTCO_2e$ from ecosystem restoration (reforestation and prairie restoration), 121,154 $MTCO_2e$ from regional reforestation associated with adding conservation lands, 16,250 $MTCO_2e$ through biochar amendments to agricultural soils, and 6,250 $MTCO_2e$ from adoption of conservation agriculture.

Table 33: GHG Reductions from AFOLU Sector Measures

AFOLU Measure	Annual Average Emissions Reduction ($MTCO_2e$)	Cumulative Emissions Reduction through 2030 ($MTCO_2e$)	Cumulative Emissions Reduction through 2050 ($MTCO_2e$)
Wetland Restoration	400	2000	10,000
Land Restoration	5,000	25,000	100,000
Conservation Agriculture	250	1250	6,250
Reforestation on Conservation Lands	5,248	48,000	131,200
Soil Biochar	650	3250	16,250
Total Emissions Reductions	11,548	79,500	263,700

7.7.5.2. Co-Benefits from AFOLU Measures

Across the Cleveland-Elyria MSA, existing urban forests provide highly valuable environmental services. Trees intercept roughly 10-20% of rainfall, reducing stormwater treatment and limiting combined sewer overflow events. Urban trees also provide important cooling benefits in cities, offsetting the urban heat island effect. These services in addition to air pollution removal and property value gains are worth more than $28 million annually for the City of Cleveland alone.

Beyond climate mitigation, wetlands offer several ecosystem services. They act as natural sponges. They reduce flood peaks through storage and slow release of stormwater, which is increasingly important in the face of more severe weather.[359] Riparian and downstream wetlands improve watershed resilience, because they sustain baseflows during drought and intercept nutrient-rich runoff from agriculture and urban areas. These systems filter nitrogen and phosphorus, preventing harmful algal blooms and improving the quality of aquatic habitats. Wetland restoration also boosts ecological co-benefits by reducing habitat fragmentation for species and increasing biodiversity. Taking concerted action to protect endangered wetland ecosystems from development pressures in growing areas and to restore degraded wetlands in legacy communities can boost these ecological co-benefits and make ecosystems more resilient to the changing climate.

Urban wetland restoration projects face challenges like invasive species, altered hydrology, and habitat fragmentation, but when designed with connectivity and community use in mind, they can simultaneously improve ecological health, reduce infrastructure costs, and raise surrounding property values. Long-term studies have found that naturally colonized wetlands often outperform planted ones in terms of carbon sequestration. This is likely due to faster growing, opportunistic plant communities, though these systems may also require more active herbivore management to maintain long-term function.

Many of the decarbonization benefits from the AFOLU sector scale with land surface area. Thus, the greatest regional decarbonization benefits will occur through actions focused on areas with more land (primarily rural areas with a low population density). The concentration of LIDACs is in urban areas, making it difficult to ensure that LIDACs enjoy these co-benefits. However, there are substantial cooling and flood reduction benefits from urban trees. Therefore, urban tree planting will have strong positive co-benefits in urban areas while the decarbonization benefits will be lower than rural areas with higher tree density. LIDACs are more likely to have impervious pavement, which results in more urban heat effects and more flooding potential. The addition of trees and green infrastructure will help mitigate the heat and flooding impacts on these communities.

Cleveland-Elyria MSA Benefits Analysis

8. Cleveland-Elyria MSA Benefits Analysis

8.1. Quantified Estimates of Co-Pollutant Reductions

While the emissions reduction measures outlined in this CCAP have largely focused on reductions in GHG emissions, there will also be significant reductions in co-pollutants. This section presents quantified estimates that illustrate the predicted relationship between CO_2 emissions and other emissions that are harmful to human health such as SO_2, NO_x, VOCs, and $PM_{2.5}$. Such emission reductions will improve air quality and reduce the negative impacts on human health.

Table 34 presents the combined reductions in co-pollutants across emissions reduction measures, while **Tables 35** to **39** provide estimates from individual sectors.

Table 34: Combined Reductions in Co-Pollutants from All Measures by County[360]

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	1,515.5	9,266.6	2,542.9	2,962.8
Geauga	127.5	963.3	433.6	518.4
Lake	1,662.2	1,937.0	559.5	554.8
Lorain	310.8	2,064.8	804.0	908.8
Medina	196.3	1,575.7	625.9	646.8
Total	**3,812.3**	**15,807.4**	**4,965.9**	**5,591.6**

Table 35: Reductions in Co-Pollutants from Clean Electricity Measures by County

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	1,148.0	624.9	11.6	74.3
Geauga	84.5	46.0	0.9	5.5
Lake	192.1	104.6	1.9	12.4
Lorain	231.6	126.1	2.3	15.0
Medina	139.4	75.9	1.4	9.0
Total	**1,795.6**	**977.5**	**18.1**	**116.2**

Table 36: Reductions in Co-Pollutants from Building Measures by County

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	38.5	2,683.7	1,043.3	1,755.8
Geauga	10.5	167.4	323.4	369.1
Lake	12.0	459.7	386.7	515.6
Lorain	17.5	555.9	557.1	689.3
Medina	13.5	333.8	424.2	503.9
Total	**92.0**	**4,200.5**	**2,734.7**	**3,833.7**

Table 37: Reductions in Co-Pollutants from Industry Measures by County

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	241.7	1,940.3	1,323.1	1,062.6
Geauga	26.1	449.5	97.0	138.6
Lake	1,440.2	549.6	137.1	12.4
Lorain	40.6	411.7	204.8	187.6
Medina	29.5	525.9	174.0	122.7
Total	**1,778.1**	**3,877.0**	**1,936.0**	**1,523.9**

Table 38: Reductions in Co-Pollutants from Transportation Measures by County

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	42.5	1,956.8	80.3	34.1
Geauga	3.4	157.8	6.5	2.8
Lake	9.5	439.3	18.0	7.7
Lorain	10.3	475.5	19.5	8.3
Medina	7.5	346.7	14.2	6.1
Total	**73.2**	**3,376.1**	**138.5**	**59.0**

Table 39: Reductions in Co-Pollutants from Waste and Material Management Measures by County

County	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	44.7	2,060.8	84.6	36.0
Geauga	3.1	142.6	5.9	2.5
Lake	8.3	383.8	15.8	6.7
Lorain	10.8	495.7	20.4	8.7
Medina	6.4	293.3	12.0	5.1
Total	**73.3**	**3,376.2**	**138.7**	**59.0**

Table 40 breaks down reductions in co-pollutants from large emitters across the MSA. Industrial process and operations decarbonization can reduce harmful emissions, which directly improves public health. Electrification reduces noise and vibration, which makes work environments safer; improvements in water usage efficiency decrease the amount of industrial water waste; and new industrial support will create new job opportunities in the region.

Table 40: Detailed Reductions in Co-Pollutants from Large Emitters by County [361]

County	City	LIDAC	Company	Tons of SO_2	Tons of NO_x	Tons of VOCs	Tons of $PM_{2.5}$
Cuyahoga	Cleveland	Yes	Charter Steel Cleveland	0.55	0.92	0.17	0.42
		No	Cleveland Clinic	0.04	5.42	0.39	0.62
		Yes	Cleveland-Cliffs Cleveland Works	17.85	0.24	5.61	0.11
		Yes	Corix	3.78	2.42	0.16	0.00
		Yes	Dominion Energy Ohio	36.42	23.36	1.52	0.00
		Yes	Howmet Aerospace, Inc.	0.07	3.84	6.54	2.39
		Yes	Lincoln Electric Co.	0.02	1.37	2.32	0.85
		Yes	Medical Center Company	4.91	3.15	0.20	0.00
	Broadview Heights	No	Royalton Road Sanitary Landfill	0.47	6.62	1.03	1.00
	Euclid	Yes	Terves, Inc.	0.07	3.84	6.54	2.39
	Solon	No	Cuyahoga Regional Sanitary Landfill	0.22	3.15	0.49	0.47
	Cuyahoga Total			**64.40**	**54.33**	**24.97**	**8.25**
Lake	Fairport Harbor	Yes	Carmeuse Lime, Inc. Grand River Operations	6.69	14.03	2.92	31.27
	Painesville	Yes	Lubrizol Corp.	0.33	2.09	4.67	0.69
		Yes	Painesville Municipal Electric Plant	0.11	0.07	0.00	0.00
	Painesville Township	Yes	Lake County Solid Waste Facility	1.29	18.18	2.82	2.74
	Lake Total			**8.69**	**34.37**	**10.41**	**34.7**
Lorain	Avon Lake	No	Ford Motor Company - Ford Ohio Assembly Plant	0.03	1.56	2.65	0.97
	Grafton	Yes	Ross Incineration Services, Inc.	1.81	52.54	3.97	3.84
	Elyria	Yes	Lorain County Landfill I &II	3.85	54.21	8.42	8.16
	Lorain	Yes	US Steel - Lorain Tubular Operations	0.00	0.01	0.00	0.00
		Yes	West Lorain	48.45	31.08	2.02	0.00
	Lorain Total			**54.14**	**139.4**	**17.06**	**12.97**
Medina	Seville	No	Wadsworth	0.01	12.63	4.79	0.45
	Medina Total			**0.01**	**12.63**	**4.79**	**0.45**

Table 41, below, quantifies the value of public health benefits from improved air quality. Staff utilized U.S. EPA's COBRA model to develop these estimates of annual benefits. Because co-pollutant reductions are based on data from the 2020 NEI, staff used the closest available COBRA analysis year (2023). Staff matched emissions reductions from each sector to the corresponding emissions tiers within COBRA (e.g., on-road vehicles to highway vehicles) and used COBRA's default 2% discount rate.

Table 41: Total Air Quality-Related Health Benefits from All CCAP Measures

Health Measure	Annual Impact	Total Annual Health Benefit
Avoided Premature Deaths (Low)	219	$3.2 billion
Avoided Premature Deaths (High)	423	$6.2 billion
Avoided Heart Attacks	119	$10 million
Avoided Cases of Lung Cancer	12	$518,000
Avoided Cases of Alzheimer's Disease	84	$1.9 million
Avoided Cases of Parkinson's Disease	12	$280,000
Avoided Strokes	10	$641,000
Avoided Cases of Asthma	562	$42.9 million
Avoided Asthma Attacks	99,469	$12.4 million
Avoided Work Loss Days	20,048	$5.9 million
Avoided Lost School Days	110,217	$34 million
Total Health Benefits (Low)		**$3.3 billion**
Total Health Benefits (High)		**$6.3 billion**

As the results illustrate, the measures included in this CCAP will provide substantial public health benefits for the Cleveland-Elyria MSA. These measures will prevent 219-423 premature deaths, 119 heart attacks, and nearly 100,000 asthma attacks every year. In total, these measures will provide $3.3-$6.3 billion in health benefits each year after CCAP measures are fully implemented.

8.2. Additional Benefits

Nearly all the measures described in this report have additional benefits beyond reductions in GHG emissions. Below we describe the benefits that exist across sectors. As **Figure 38** shows, these benefits can be characterized as falling into four categories: (1) Health benefits, (2) Environmental benefits, (3) Social benefits, and (4) Economic benefits.

Figure 38: Co-Benefits of Emissions Reduction Measures across Sectors

Table 42 provides an outline of the measures identified and proposed throughout the CCAP, organized by sector, and describes additional benefits and disbenefits. This list is not exhaustive; however, it does emphasize that, while there are some potential downsides of implementing CCAP measures, they will provide substantial benefits for residents of the Cleveland-Elyria MSA.

Table 42: Benefits and Disbenefits of Measures by Sector

Commercial & Residential Energy		
Measure Name / Description	**Metrics**	**Benefits / Disbenefits**
Intelligent Grid Management Systems - Modernize distribution system management to improve demand response, peak management, engagement of grid-scale storage for frequency regulation and voltage control.	% of distribution grid upgrades across communities; % of smart meters installed in the community	Will improve grid reliability, facilitate complex grid management, improve response to demand, and result in energy efficiency systems.
Energy Efficiency Retrofits for Existing Buildings	% of buildings retrofitted % decrease in average power use of buildings.	Large-scale demand reduction, improved indoor air quality and subsequent health, lower utility bills, and reduced energy insecurity.
Electrification & Renewables	% of homes electrified and upgraded	Sharp emissions drop from heating; utilities shift to supporting clean peak demand.

Low-Embodied Carbon Construction	% of new public housing that follows low-carbon embodied specifications.	Reduced life-cycle carbon intensity of regional building stock; increased demand for low-carbon supply chains.
High-Performance New Construction	% of new commercial buildings install SEMS	Long-term energy cost stabilization; new housing stock aligned with climate targets.
Energy Burden Fairness	Number or % of Households with Above Average, High, or Severe Energy Burden	Improved housing quality, fewer energy disconnections, and greater resilience for marginalized populations.
Grid-Interactive Buildings & Demand Flexibility	Total % of buildings with at least one grid-interactive system	Grid resilience improves; reduced blackouts; higher renewable penetration without infrastructure overbuild.
Urban Heat Island Mitigation	% of flat-roof buildings that have adopted reflective or green roofing. Decrease in ambient summer temperatures within urban core	Reduced cooling loads, better public health, and ecosystem restoration in urban areas.
Industrial Energy & IPPU Sector		
Measure Name / Description	**Metrics**	**Benefits/ Disbenefits**
Switch to Hydrogen	% of fuel switched	Improved air quality
Carbon capture at Cleveland Works with geologic sequestration	~60-90% carbon capture	Improved air quality, though these benefits would be lower if Cleveland Works continues using coke for steel production
Energy Audits	20% energy consumption reduction across industry by 2030 Creation of facility decarbonization plans	Reduced demand on grid
Reduced Industrial Waste	Waste reduction of 30% by 2030, zero waste by 2050	Reduction in co-pollutants
Replacement of BF-BOF system at Cleveland Works with a green steel alternative	Implementation of H2DRI + EAF or MOE by 2050	Improved air quality
Transportation & Mobile Sources		
Measure Name / Description	**Metrics**	**Benefits/ Disbenefits**
Expand BEV charging infrastructure	Number of EV chargers installed Number of EVs purchased within LIDACs	Benefits: reduced air pollution, improved public health, lower transportation costs, new jobs for EV installation Disbenefits: increased traffic in and around areas with EV chargers
Expand networks of protected bike lanes, off-street trails, lane conversions, and pedestrian-only zones	Number of miles per year of protected bike lanes, trails, and lane conversions	Benefits: health benefits from active transportation; increased mobility options for people who cannot or do not want to drive; reduction in traffic crashes/improved road safety Disbenefits: increased risk of traffic crashes from walking and biking

Agriculture, Forestry, and Other Land Uses (AFOLU)		
Measure Name / Description	**Metrics**	**Benefits/ Disbenefits**
Tree Carbon Capture Any net improvement in the number of street trees and regional forest cover will sequester carbon and provide numerous co-benefits	100 street trees, Change in % forest canopy using national Tree Canopy Cover data	Shading/cooling and canopy interception of rainfall; Less energy needed for cooling, less storm water in yard, but more tree maintenance cost

Traffic Safety and Physical Activity Co-Benefits: As discussed in Section 7.5.5, reducing VMT would also lower the number of injuries and deaths on region's roads and increase physical activity. This analysis uses guidance from the U.S. Department of Transportation (USDOT) and the Federal Transit Administration (FTA) on the value of avoided premature deaths and injuries.[362] **Table 43** highlights the value of these co-benefits. All values are expressed in 2023 dollars, using a 2% discount rate.

Table 43: Total Value of Traffic Safety & Physical Activity Co-Benefits of VMT Reduction (Millions of 2023$, Net Present Value)

County	Average Annual Value of Avoided Traffic Fatalities	Average Annual Value of Avoided Traffic Injuries	Average Annual Value of Increased Physical Activity	Average Annual Total Value of VMT Reduction	Cumulative Value of VMT Reduction (2025-2050)
Cuyahoga	252.3	80.3	2,667.9	3,002.4	78,063.6
Geauga	26.9	8.5	181.9	217.2	5,648.4
Lake	48.8	15.4	379.6	443.9	11,514.0
Lorain	75.4	23.8	748.9	848.0	22,049.2
Medina	58.1	18.3	279.0	355.4	9,240.7
MSA Total	**463.5**	**146.4**	**4,257.2**	**4,867.0**	**126,543.0**

The MSA would enjoy average annual benefits of nearly $4.9 billion. From 2025-2050, cumulative benefits would total roughly $126.5 billion. Most (87%) of these benefits would come from increased physical activity, followed by reduced traffic fatalities (10%) and avoided serious injuries (3%) on the region's roads. Though the risks of increased crashes among cyclists and pedestrians could offset some (11%) of this value (see Section 8.3 for more discussion of this disbenefit), the physical activity benefits of shifting people to active transportation are so large that they justify the investment on their own.

8.3. Potential Disbenefits of Emissions Reduction Measures for Cleveland-Elyria MSA

There are both measure-specific and cross-sector disbenefits to implementation that require careful consideration and anticipation. Here we provide a general overview of potential disbenefits across a range of measures.

Cost Prohibitive: Recommended measures will require substantial investments to implement, as well as major infrastructural improvements. The costs involved may prove prohibitive, which can delay, or even serve as a barrier, to implementation. Disbenefits can also involve long-term costs to maintain interventions.

Workforce Displacement: Job losses, particularly for lower-skilled workers, due to the adoption of new technologies that require unique expertise. If there are no specific training or upskilling programs in place, low skilled workers may be displaced, and the benefits of new job creation may not extend to them. Job displacement was noted as a primary concern raised by community members in engagement sessions, particularly in places heavily reliant on industry for employment.

Permitting Processes: Massive infrastructure improvements will require permitting, which could add time to or delay implementation.

Increased Property Taxes: Improvements that result in energy efficiency and lead to the development of high-performance buildings also increase property values. Increased property values can result in increased property taxes and could potentially displace marginalized residents.

Poor Craftsmanship or Installation: One potential disbenefit is poor quality retrofit work, which can create indoor air quality issues from off-gassing and lead to additional costs. Ensure the quality of installation and have trained installers and inspectors to prevent this. Lack of quality installers and inability to determine the qualifications of installers are potential barriers, but adequate inspection and training (e.g., certification) can reduce this barrier to adoption.[363]

Industry Uncertainty: Consumers may face challenges as they navigate the market; many new companies emerge that may face smaller and uncertain profit margins and consequently experience higher rates of failure. If the company or installer changes hands, goes bankrupt, or goes out of business, this may create long-term disbenefit for consumers when it comes to post-purchase experiences.[364]

Maintenance and Buy-in for Tree Canopy Restoration: Tree planting efforts that aim to restore the tree canopy will also impose maintenance costs and require public buy-in. This might prove a hurdle to implementation. Community members expressed concerns about the poor maintenance of existing trees. Many residents worried that the burden of maintenance would fall on homeowners or create safety hazards with increased frequency of severe storms. This represents a significant disadvantage for residents.

Negative Impact on Future Development: A potential disbenefit associated with increasing tree canopy in urban neighborhoods (e.g., efforts to regreen vacant parcels) could be the delay or prevention of future TOD through lower development densities. There is also a disbenefit when resources are spent on trees in a neighborhood that are later cut down for new development, a less than optimal use of critical resources.

Increased Risk of Mosquito Exposure: Restored wetlands, often not situated near dense populations or buildings, may pose a risk of increased mosquito infestation and associated disease transmission threats.

Increase in Cyclist and Pedestrian Crashes: In the short- to medium-term, there may be an increase in the number of injuries and fatalities from pedestrians and cyclists as people shift away from driving. The number of pedestrian fatalities in the MSA doubled over the past decade from 13 in 2013 to 26 in 2022; this increase reflects a broader trend, as the number of pedestrian deaths rose by similar amounts statewide and nationally during that period.[365]

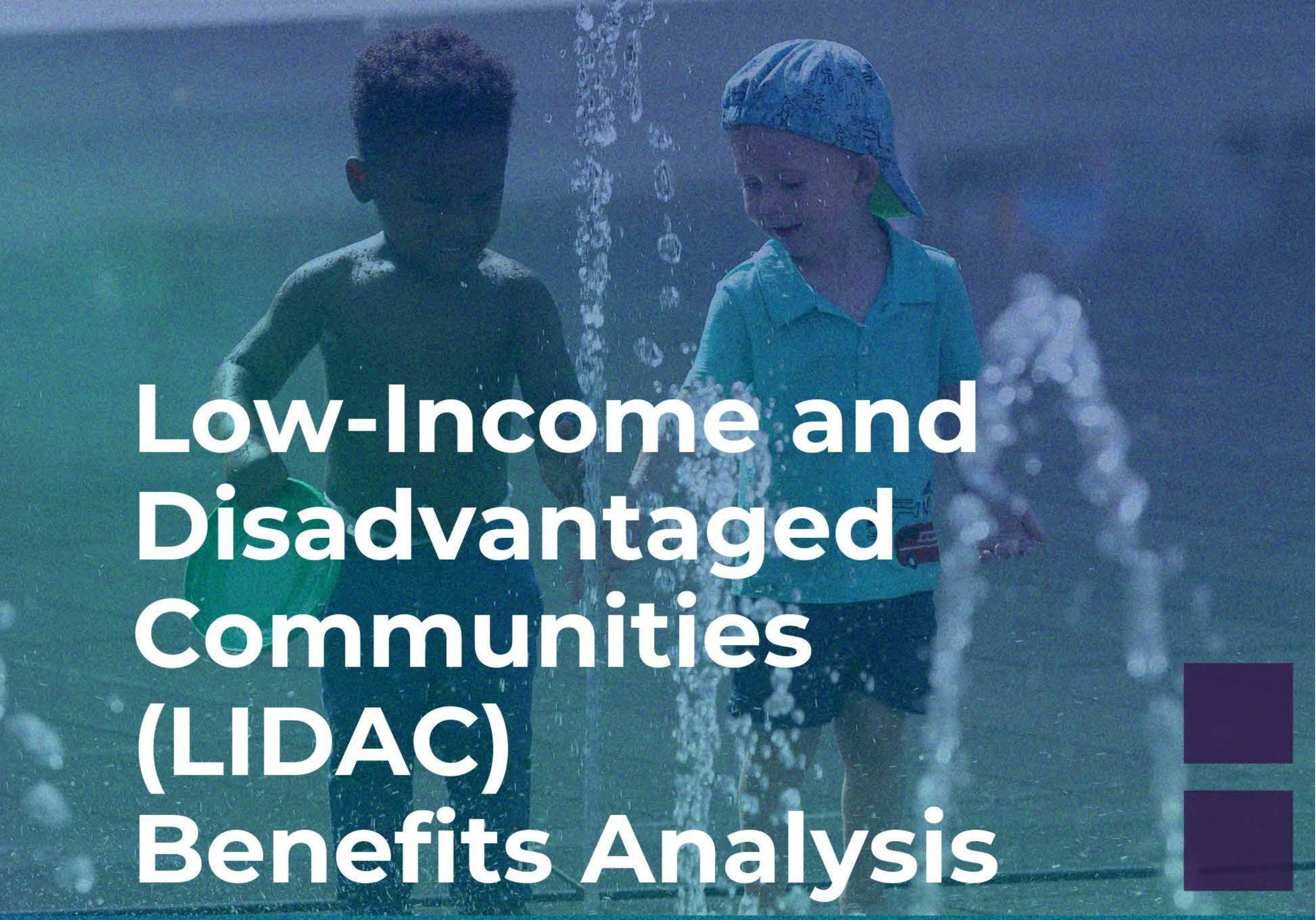
As the number of person miles for biking and walking increases across the MSA, there may be a comparable increase in injuries and fatalities due to higher levels of exposure. This increase could be modest and short-term in nature, as an increase in the number of people biking and walking tends to create a "safety in numbers" effect.[366] Additionally, as communities throughout the MSA increase the amount of protected infrastructure for active transportation, injury and fatality rates for cyclists and pedestrians will likely decrease.

To calculate the potential disbenefit of an increase in cyclist and pedestrian crashes, staff followed the methodology outlined in Section 7.5.5 and Appendix A to estimate the change in annual person miles of biking and walking across the MSA from 2025-2050. Staff then entered these data into the WHO HEAT model.

Under a worst-case scenario, in which the fatality rate for biking and walking remains at fixed levels, the increase in crash deaths among cyclists and pedestrians would be enough to offset all avoided traffic fatalities in the MSA. However, when one includes the health benefits from increased active transportation, it becomes clear that the total benefits far outweigh the potential disbenefits. Under this worst-case scenario, the increased risk of crashes only offsets around 11% of the total benefits of VMT reduction.

These data emphasize that communities across the Cleveland-Elyria MSA should act quickly to build out a network of protected active transportation infrastructure to reap the benefits of VMT reduction and reduce the potential disbenefits from traffic crashes.

Low-Income and Disadvantaged Communities (LIDAC) Benefits Analysis



9. Low-Income and Disadvantaged Communities (LIDAC) Benefits Analysis

This section evaluates the extent to which CCAP emissions reduction measures will deliver reductions in GHG and air pollution emissions reductions and other benefits to LIDACs throughout the Cleveland-Elyria MSA. This analysis utilizes the same set of LIDACs that NOACA and the City of Cleveland identified as part of the Cleveland-Elyria MSA's PCAP, based upon the Climate and Economic Justice Screening Tool (CEJST) and the Environmental Justice Screening and Mapping Tool (EJScreen).[367] These tools enable regions to assess an array of relevant indicators across a range of categories of burden in order to determine if a community qualifies as a LIDAC.[368]

LIDACs are those Census tracts with high concentrations of residents with low incomes and disproportionate exposure to environmental or climate burdens. Additionally, they are at greater risk of exposure to climate hazards due to social and economic vulnerabilities. Past government processes and policies, such as redlining, have driven disinvestment and contributed to the barriers to sustainability and resilience that LIDACs face. A LIDAC benefits analysis is a critical step to pave the way to outcomes that can spur improved sustainability and greater resilience for residents of LIDACs.

9.1. Low-Income and Disadvantaged Communities (LIDAC) Benefits Analysis

The *Cleveland-Elyria MSA Priority Climate Action Plan* identified 253 2010 Census tracts as LIDACs, based upon data from CEJST and EJScreen. Both tools provide data on a combination of socioeconomic attributes (e.g. income, level of education, age) and environmental indicators (e.g. $PM_{2.5}$, diesel particulate matter, hazardous waste proximity) to determine LIDAC status.

CEJST provides information on the environmental and economic burdens that communities face within the U.S. It identifies eight categories of burdens and classifies a Census tract as disadvantaged if it is at or above the 90th percentile for one or more burdens and is at or above the 65th percentile for low income. EJScreen combines data for 13 environmental indicators and seven socioeconomic indicators at the Census tract level. It also combines each of the environmental indicators with a supplemental demographic index that includes five indicators: low income, unemployment rate, limited English-speaking households, less than high school education, and low life expectancy to create a series of Supplemental Indexes (SIs). If a tract scores at or above the 90th percentile nationally on an SI, it is "burdened" for that indicator. For a list of all LIDAC Census tracts by jurisdiction within the Cleveland-Elyria MSA, please refer to Appendix C.

Roughly 43.4% of Census tracts within the Cleveland-Elyria MSA are LIDACs. These tracts are primarily concentrated in Cuyahoga County (88%), with most of these located within the City of Cleveland (66% of MSA total). Cleveland neighborhoods with the highest absolute number of LIDACs include Glenville, Broadview-Slavic Village, Hough, and Mount Pleasant, though there are LIDACs in nearly every statistical planning area (SPA).[369] In 24 neighborhoods nearly every Census tract, at least 80% of the Census tracts in that neighborhood, qualify as a LIDAC. Other municipalities with a significant absolute number of

LIDACs include Lorain, Euclid, East Cleveland, and Elyria.[370] Additional cities with a significant proportion of LIDACs include Maple Heights, Garfield Heights, Painesville, and Warrensville Heights.

Table 44 provides the distribution of LIDACs across MSA counties, which illustrates the concentration and uneven dispersion of LIDACs in the region. **Tables 45** and **46**, in turn, identify the neighborhoods/SPAs and cities with the highest concentration of LIDACs.
Following the tables below, **Figure 39** provides a map of LIDACs.

Table 44: Distribution of LIDAC Census Tracts by County

County	Total LIDAC Tracts	% of MSA LIDACs in County
Cuyahoga	222	87.7%
Geauga	2	0.8%
Lake	3	1.2%
Lorain	26	10.3%
Medina	0	0%
MSA Total	**253**	**100%**

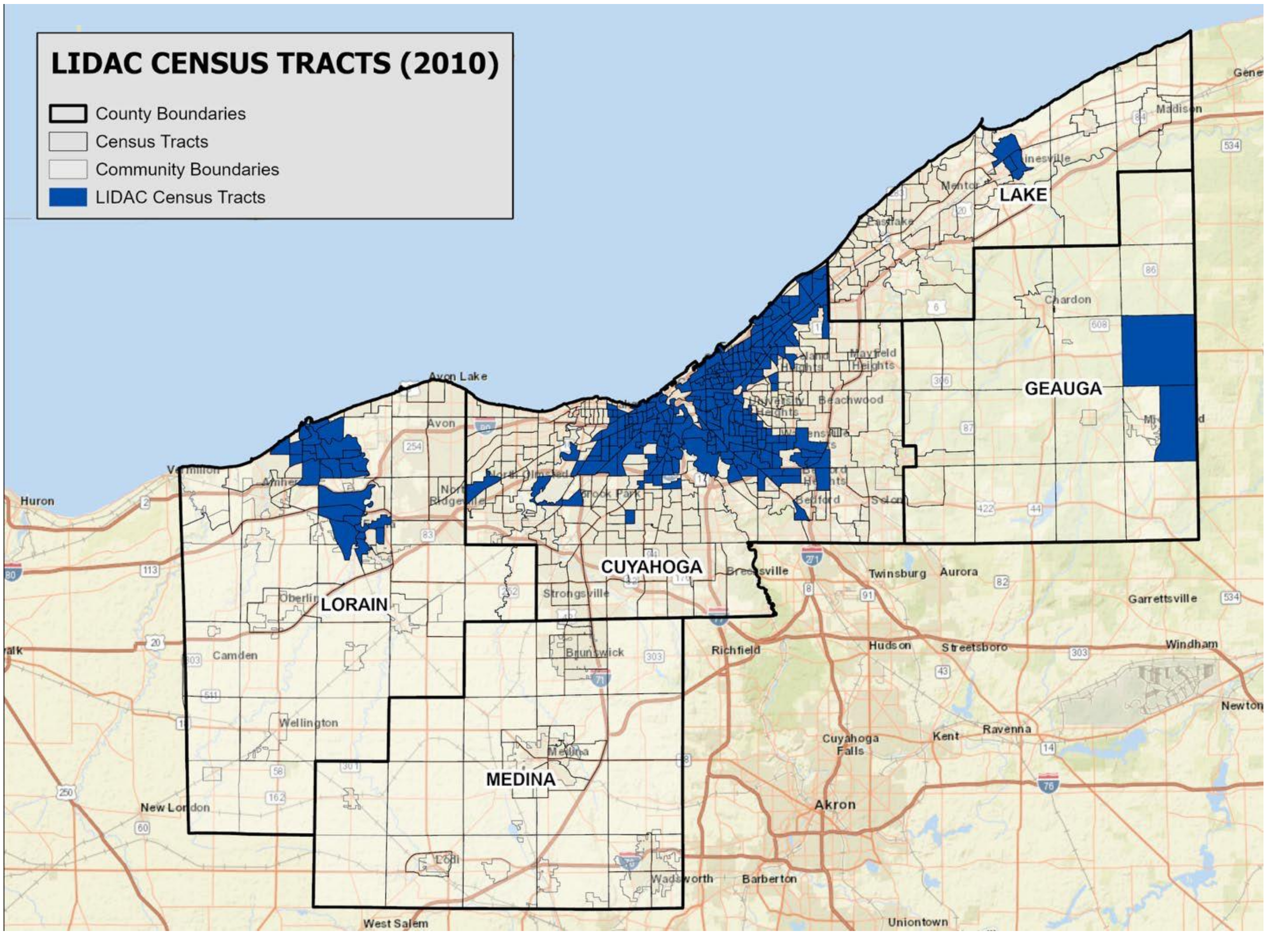
Table 45: Cleveland Neighborhoods with the Highest Concentrations of Disadvantage

Neighborhood/Statistical Planning Area	Total LIDAC Census tracts	Total Census tracts At Least 5 CEJST Categories of Burden
Glenville	14	12
Old Brooklyn	9	1
Hough	8	9
Broadview-Slavic Village	11	8
Mount Pleasant	8	2

Table 46: Cities Outside of Cleveland with Highest Concentrations of LIDACs [371]

City/Township	Total LIDAC Census tracts	Total Census tracts in City	LIDACs as % of Total Tracts
East Cleveland	11	11	100%
Warrensville Heights	5	6	83%
Sheffield Township	5	6	83%
Euclid	12	16	75%
Lorain	17	23	74%
Garfield Heights	6	10	60%
Elyria Township	3	5	60%
Maple Heights	4	7	57%
Middlefield Township	1	2	50%

Figure 39: LIDAC Census Tracts in Cleveland-Elyria MSA



Though there are LIDACs in every county other than Medina County, the overarching pattern of their location indicates a high degree of spatial concentration of disadvantage. LIDACs often are disproportionately composed of populations that are particularly vulnerable to climate hazards.

Table 47 displays the 10 MSA Census tracts that exceed at least seven CEJST categories, while **Table 48** lists the 13 tracts that score at the 90th percentile or above on at least 12 EJScreen SIs. All of the Census tracts in these tables are located within Cuyahoga County, which illustrates the concentration of burden within the region.

Table 47: Cleveland-Elyria MSA Census tracts that Exceed Seven CEJST Categories

City	Neighborhood/Statistical Planning Area	Census tract	Number of CEJST Categories Exceeded
East Cleveland		39035150400	8
		39035150400	8
Cleveland	Brooklyn Center	39035105602	7
	Central	39035108701	7
	Central	39035109701	7
	Broadway-Slavic Village	39035110501	7
	Broadway-Slavic Village	39035110801	7
	St. Clair-Superior	39035111700	7

Table 48: Census tracts at or above the 90th Percentile for at least 12 EJScreen SIs

City	Neighborhood/Statistical Planning Area	Census tract	Number of EJScreen SIs At or Above the 90th Percentile
Cleveland	Cudell	39035101101	13
	Edgewater	39035101800	13
	Detroit Shoreway	39035101901	13
	Hough	39035112301	13
	Cudell	39035101400	12
	Cudell	39035101501	12
	West Boulevard	39035101603	12
	West Boulevard	39035102101	12
	West Boulevard	39035102300	12
	West Boulevard	39035102402	12
	Goodrich-Kirtland Park	39035108301	12
	Broadway-Slavic Village	39035110901	12
	Central	39035197900	12

As these data suggest, communities within Cuyahoga County, particularly the City of Cleveland and a handful of First Ring Suburbs, face severe burdens from economic and environmental disadvantages.

The socioeconomic and racial demographic characteristics of LIDACs are different than the overall MSA. While nearly one-third of MSA residents identify as people of color, they make up the majority (51.5%) in LIDACs. While 28.7% of all residents qualify as low income, that share reaches 44.3% in LIDAC tracts. The unemployment rate in LIDACs is higher than in the region.

9.2. Meaningful LIDAC Engagement

Community engagement with LIDACs to prepare this CCAP entailed multiple concurrent processes to collect community input. The City of Cleveland conducted several rounds of engagement within the city boundaries to targe LIDACs. NOACA commissioned a consulting firm, Joel Ratner Community Consultants, to gather community input in Geauga, Lake, Lorain, and Medina Counties. Lastly, a small subset of individual Cuyahoga County municipalities with LIDACs engaged and collected feedback from their residents.

9.2.1. City of Cleveland LIDAC Engagement

Cleveland's MOS aimed to include groups and neighborhoods that were underrepresented during the PCAP engagement. Community members provided feedback and insight through multiple sources, including community roundtable discussions, educational workshops, and a survey. Efforts to communicate the findings included presentations to the City of Cleveland's Climate Advisory Council & Steering Committee (meetings held in July and October 2024) and an outline in the 2025 CAP update.

Cleveland Community Climate Action Survey: The City collected survey data from 368 respondents during July 22-August 16, 2024. The survey was available in English and Spanish. The survey aimed to gather insight into the central goals and objectives the City should prioritize in its CAP update. City staff asked respondents to evaluate possible climate actions. Key findings from the survey included expressed from respondents for desire for:

(1) Increased access to greenspaces;
(2) Improved access to food and transportation;
(3) Job and other economic opportunities;
(4) Climate education and improved climate literary; and
(5) Litter cleanup and better waste management practices.

While a helpful tool, survey respondents skewed middle-class and advantaged; they were not representative of the city's demographics or of LIDACs more broadly. Survey respondents were 73% white, 76% with a bachelor's degree or higher, and 32% with incomes $100,000 or over. Nonetheless feedback gleaned from survey responses helped ensure more diverse representation at the in-person community roundtables.

Community Roundtables: The City of Cleveland commissioned Sustainable Economies Consulting and Free by Design to conduct six community roundtables targeting nine neighborhoods with the City of Cleveland during August and September 2024[372]. The consultants organized each roundtable in coordination with a community-based organization, which served as partners and co-hosts. In some instances, the consultants provided community organizations with a stipend for their efforts to recruit participants and spread the word about the roundtables. The consultants viewed the stipends as a way to garner good faith and build on established trust. The partners promoted the roundtable meetings to prospective participants with flyers and other materials distributed through a range of platforms.

The consultants selected neighborhoods based on several factors, including PCAP data on the LIDACs that stood to benefit the most from priority climate actions. These factors included: accessibility (e.g., on transit line), safety, and familiarity for residents. In total, 109 participants engaged in the roundtable discussions, with each session ranging from four to 33 participants. Of the total participants, 82% of participants were residents of the City of Cleveland, 65% were Black, 19% White, and 15% Hispanic/Latino. The majority had annual incomes of less than $50,000. The City provided a Spanish translator at the roundtable in Clark-Fulton. More detailed information and summaries of the findings from the community roundtables are available from the City of Cleveland.[373] Participants received a catered meal at most of the events and, in some instances, gift cards.

Prior to and during the workshops, participants reviewed a poster with a graph breaking down GHG and images that reveal poor air quality and low visibility over Lake Erie. Each roundtable began with a general discussion of climate change's impact on neighborhoods and a discussion of residents' aspirations for their neighborhood. A brief presentation followed this discussion, usually conducted by MOS staff. Staff members illustrated the impacts already experienced by Cleveland residents, including poor air quality, extreme heat, and more severe storms. They also outlined the risk such hazards impose on residents, such as health impacts and rising energy costs.

Next, staff members explained the five climate action focus areas: (1) Built Environment, (2) Clean Energy, (3) Clean Transportation, (4) Nature-Based Solutions, and (5) Resilient People. Participants ranked the three focus areas they considered the most important and then engaged in a breakout session to discuss those focus areas that received the highest ranks. The discussions focused on the barriers to implementation, as well as potential solutions. Additionally, the consultants asked participants about blind spots in the City's climate planning process. After the breakout sessions, participants received an exit survey.

The exit surveys provided useful insight into participants' priorities and concerns, as well as their perceptions of the benefits, as it pertains to the impact of climate change and their neighborhood. When asked about the impacts of climate change on their neighborhood that worries them the most (**Figure 40**), respondents indicated the impacts of storms (22), flooding (12), followed by the impact on plants and trees (11). Similarly, the exit surveys revealed what the participants saw as the potential benefits to efforts taken to address climate change. The top-ranked benefits of climate action (**Figure 41**) included clean water, clean air, and more trees and green space. Assistance with investments in home improvements and economic development were also key priorities and potential benefits from climate action.

Figure 40: What Are Climate Change Impacts that Worry You the Most? (City of Cleveland)

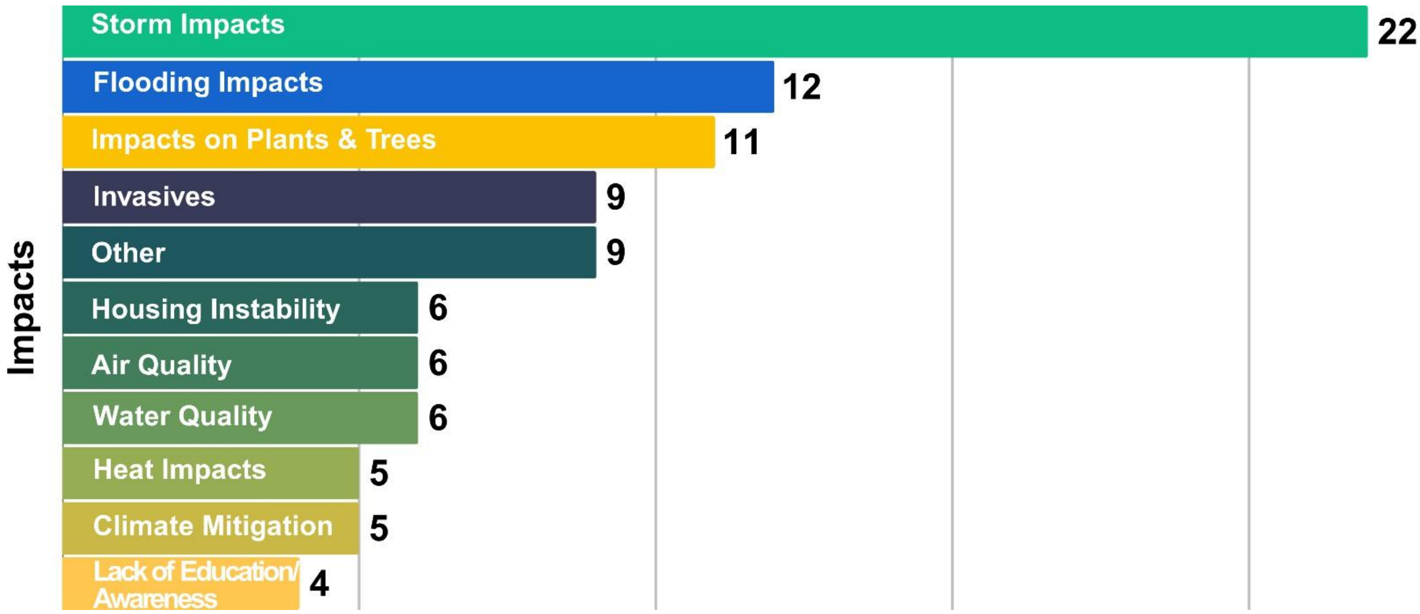
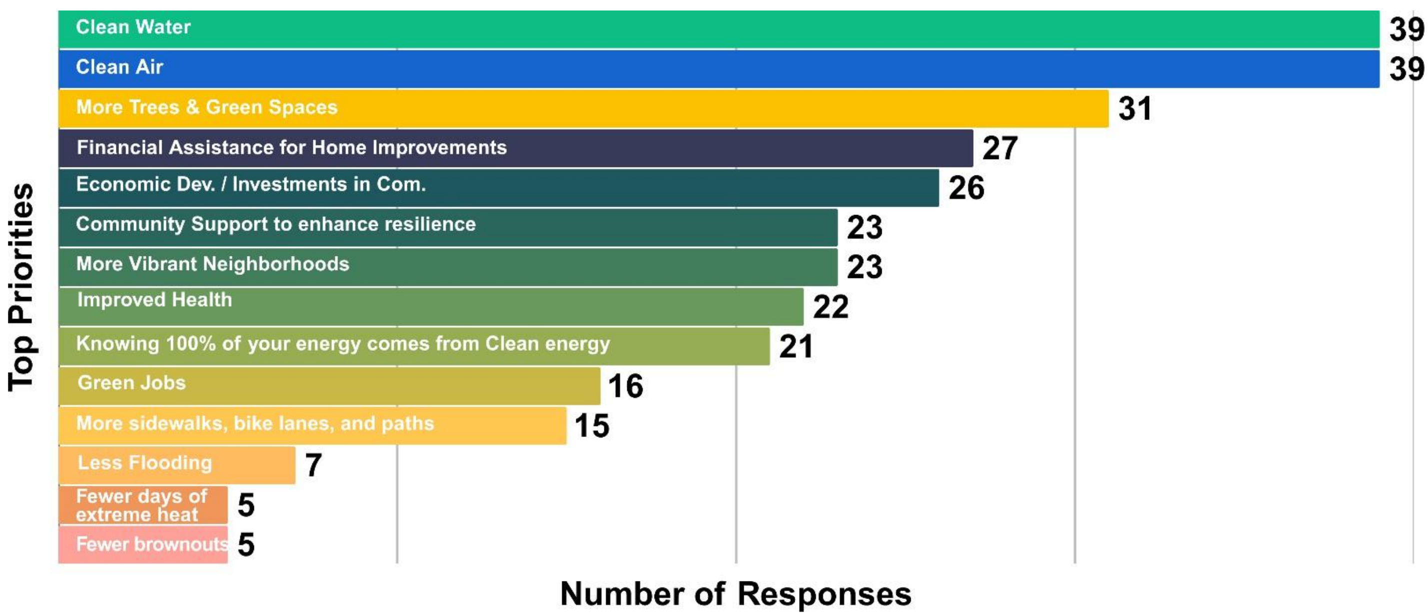


Figure 41: What Are The Top Benefits of Climate Action? (City of Cleveland)



The community roundtables provided critical insight into the priorities and concerns of participants. The City of Cleveland and CRDF team incorporated and addressed feedback as they developed CCAP strategies and measures.

There were consistent and salient themes that emerged from the roundtable discussions that were not always directly aligned with the goal of GHG reductions. However, it is critical to integrate, where possible, feedback into plan measures and objectives. Doing so helps to ensure that the proposed plan is aligned with and reflects the concerns and priorities expressed by community members. A great example of this emerged from the community's discussion of the role of schools. Participants regularly identified schools as hubs for climate action. From waste reduction, to building retrofits and improvements, to energy efficiency, to youth training for green jobs, and greater awareness to improve climate literacy, nearly every roundtable included discussions around schools as sites with great potential for impact. The desire for public education was further corroborated by open-ended responses to the exit survey prompt: “What is one resource or type of support that the City could provide to help you take action around climate change?” The most salient reply was to ensure “communities are informed and educated on issues.”

Educational Workshops: The City of Cleveland also hosted four educational workshops from September to October 2024 to take a more active and participatory approach and increase awareness of the climate planning process. The educational workshops varied in their format and content to solicit insight into the CAP in a less structured way. The workshops provided an additional touchpoint for the City to build and extend community trust with diverse constituents. Workshops targeted specific communities and facets of climate action. One of the workshops specifically focused on high-school aged youth, as youth are a key voice in climate planning but are often left out of the process.

When taken together the City of Cleveland aimed to draw on these diverse formats to gain insight into concerns and priorities of a diverse swath of community members.

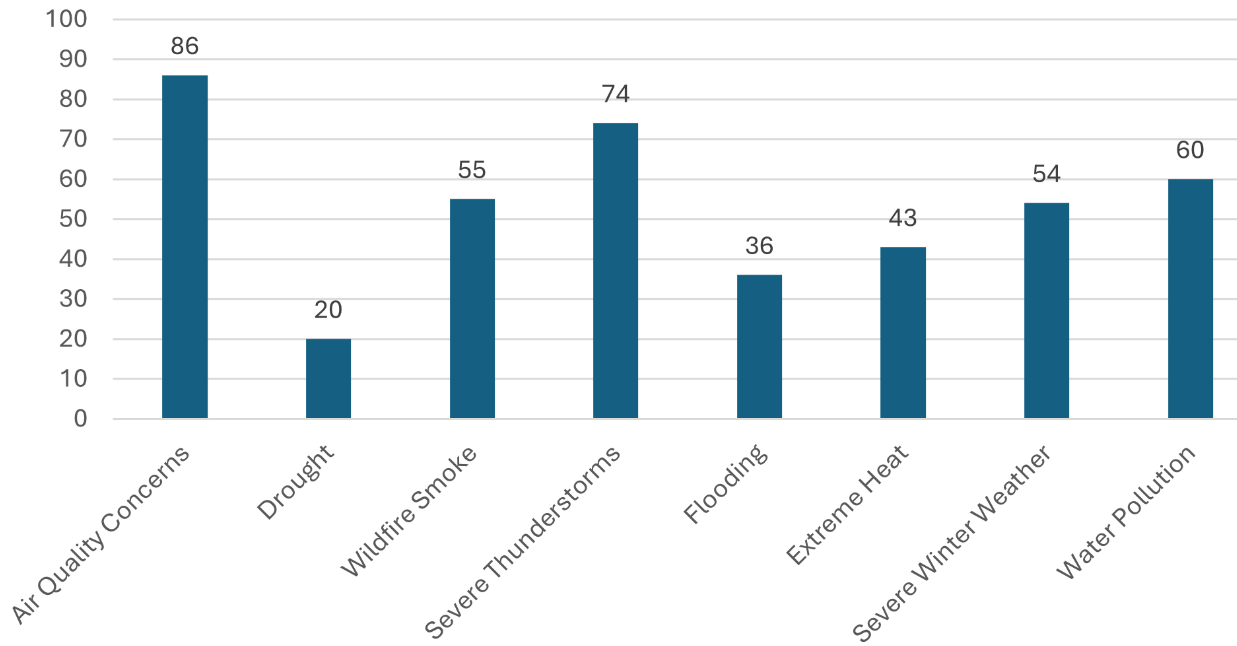
9.2.2. NOACA LIDAC Engagement

To gather input from LIDACs unrepresented in previous work, NOACA contracted with JRCP, the firm responsible for the organization and orchestration of community workshops across Geauga, Lake, Lorain, and Medina Counties. The sessions took place at various locales, including an assisted living facility, an elementary school, and a community center.

Each session followed a similar structure. First, JCRP staff gave a PowerPoint presentation that explained what NOACA’s vision and role as a metropolitan planning organization and its climate action planning efforts and potential outcomes. Often during these sessions, staff noted that NOACA’s climate action planning would position its member organizations to qualify for federal funding, with the recent award of an EPA $130 million dollar grant to close a coal-powered plant in Painesville cited as an example. Following this formal presentation, staff led a simultaneous conversation and survey. Staff encouraged participants to write their responses on a paper form, which staff collected once complete. There were some verbal exchanges in response to the prompts and as participants asked questions. In certain sessions, participants received gift cards ($25) upon the completion and return of the survey.

Of the eight categories offered: Air Quality Concerns, Drought, Flooding, Wildfire Smoke, Severe Thunderstorms, Extreme heat, Severe Winter Weather, and Water Pollution, respondents most frequently selected: Air Quality Concerns, Severe Thunderstorms, Water Pollution (see **Figure 42**). Participants frequently discussed concerns about air quality in terms of its adverse health impact on children, grandchildren and other family members who suffered from asthma and allergies.

Figure 42: What Climate Change Impacts Concern You Most? (NOACA)



Participants raised several priorities, including the impact of policies on jobs, air quality, and health. For example, while discussing the benefits of decarbonization, including the closing of a Painesville coal powered plant, several participants expressed concerns about potentially displaced workers. Simultaneously people noted that there were deleterious conditions and impacts on community health from the operation of such facilities. They expressed a heightened awareness of the impact of pollutants on respiratory conditions, causing upticks in asthma, for example. Participants also raised questions about improvements to public transportation, a particular priority for residents in the Lorain session. Concerns about transportation extended to companies and employers seen as facilitators of worker's access to reliable transportation.

For these communities, key benefits that would make them amenable to planning interventions would be workforce development and job creation, improvements to public transportation, and community health.

9.2.3. Cuyahoga County LIDAC Engagement

While there is a great deal of regional diversity, only a few locales have dedicated efforts, staff, committees, or resources to address and conduct community engagement around decarbonization. The communities in Cuyahoga County, including Cleveland Heights and Lakewood, that have engaged in such efforts provide helpful insight into how the needs and priorities of places may differ and reflect the specific conditions and capacities that their local governments face. This brief synopsis of relevant LIDAC engagement efforts in Cuyahoga County (outside the City of Cleveland) provides critical insights from Cleveland Heights, which has conducted community engagement work around decarbonization. Cuyahoga County has additionally been actively engaged with local governments and plans to roll out a pilot program to work with selected communities. The County intends to develop a more generally accessible resource guide that local governments can utilize to initiate their individualized and local climate planning efforts.

Cleveland Heights Climate Forward Plan (Cuyahoga County): Cleveland Heights, a first ring suburb, was one such community that implemented a community engagement strategy. A key objective of the Cleveland Heights Climate Action Plan was to co-design the plan with the community and, as such, the plan draws from community input collected through three workshops, two surveys, three stakeholder interviews, and involvement at ten community events held during October 2023-October 2024.[374]

Cleveland Heights' engagement indicated several overlapping concerns about impacts of climate on disadvantaged and vulnerable populations. The impact of climate on health, both mental and physical, was a shared concern, particularly given climate hazards such as poor air quality, extreme heat, and severe storms. Additionally, residents prioritized efforts to assist low-income households (especially renters) with home improvements that enhance resilience. The sessions also spotlight areas that differ and may reflect the demographics of the community. For example, participants identified adverse impacts on business owners from transit disruptions that may result from severe storms; storm-related conditions may make it difficult for transit dependent workers to reach their jobs.

9.2.4. Integrating Feedback from LIDACs into CCAP Development

Drawing on feedback and input communicated during these engagements, the CRDF team developed a synthesized list of LIDAC priorities and concerns, outlined in **Table 49**.

Table 49: LIDAC Community Priorities & Concerns from Community Engagement

City of Cleveland	Nature Based Solutions	Concern: Soil contamination
		Concern: Trees/Tree Maintenance
		Concern: Sewage
		Priority: Desire for micro-level solutions, for example, rain barrels
		Priority: Gardens and urban agriculture, though concerns also raised re: contaminated soil
		Priority: Better water quality
		Priority: Vacant lots as potential green spaces
	Built Environment	Concern: Aging housing stock presents challenges
		Concern: Damage to homes due to storms/flooding
		Concern: Damage to streets and public throughways due to storms/flooding
		Concern: Renters vulnerable due to landlord neglect/ absentee landlords
		Concern: Safety/ desire for safer neighborhoods
		Concern/ Priority: Housing code enforcement

		Priority: Affordable housing
		Priority: Financial incentives and assistance needed to make improvements/ upgrades
	Resilient People	Concern: Trust of city government and reliability of services
		Concern: Safety
		Concern: Lack of power leading to other impacts - health/safety
		Priority: Education, including training opportunities (e.g., for tree canopy maintenance), as well as curricular changes within CMSD schools, and general public awareness
		Priority: Accessible healthy food/ healthier grocery stores/ Variety of Grocery Stores
		Priority: Authentic Engagement
	Other Sectors - Transportation	Concern: Transportation-related air pollution from traffic
		Priority: Free or low-cost bike rental / protected bike lanes
NOACA – Geauga, Lake Lorain, and Medina Counties		Priority - Jobs
		Priority - Health
		Concern - Air Quality
		Concern - Health
Cleveland Heights		Priority: Assistance for low-income households to pursue home improvements that enhance resilience and facilitate improvements for renters
		Concern: Severe storms or flooding can cause transit disruptions, this can adversely impact those who are dependent on public transit, including workers
		Concern: Lack of knowledge and awareness/ Climate Literacy
		Concern: Mental health (youth climate anxiety)
		Concern: Poor air quality, extreme heat, and severe storms impact on health
CC4CC CWRU Community Event in East Cleveland, OH*		Priority - Clean Water
		Priority - Clean Air
		Priority - More Trees/ Green Space
		Priority - Assistance for Improvements to Home
		Priority - Economic Dev. / Investments in the Community
		*While the event orchestrated by CWRU was not part of or organized for the purposes of CRDF planning, the exit survey provides crucial feedback from a community that is severely burdened. Cited above are the top 5 ranked from the exit survey administered at the event.

9.3. Analysis of Benefits & Disbenefits of Emissions Reduction Measures for LIDACs

9.3.1. Benefits of Emissions Reduction Measures for LIDACs

LIDACs will benefit both directly and indirectly from measures emissions reductions measures across sectors. Targeted investments in LIDACs can accelerate the impact of these measures. **Table 50** outlines the specific measures that are most likely to produce LIDAC benefits. Impacts fall into four categories: health, economic, social, and environmental.

Table 50: Summary of Benefits of Emissions Reduction Measures for LIDACs

Measure	HEALTH: Improved public health outcomes	ECONOMIC: Job creation, economic growth, decrease or stabilize future energy costs	SOCIAL: Improved climate resilience, improved access to services, education, and social well being	ENVIRONMENTAL: Ecological, Improved access to green spaces
Clean Electricity - Intelligent Grid Management System		X		
Building Efficiency and Electrification - Energy Efficiency Retrofits	X	X	X	
- Electrification & Renewables	X	X		
- High-Performance New Construction		X		
- Energy Burden Fairness		X		X
Nature Based Solutions - Urban Heat Island Mitigation	X	X	X	X
- Tree Carbon Capture	X			X
Light-Duty Vehicle Electrification - Expand BEV Charging Infrastructure	X	X		

Measure	HEALTH: Improved public health outcomes	ECONOMIC: Job creation, economic growth, decrease or stabilize future energy costs	SOCIAL: Improved climate resilience, improved access to services, education, and social well being	ENVIRONMENTAL: Ecological, Improved access to green spaces
Vehicle Miles Traveled (VMT) Reduction Expand network of protected bike lanes, off-street trails, land conversions, and pedestrian-only zones	X			
Alternative Fuels/ Carbon capture	X			
Reduced Industrial Waste	X			X

A key co-benefit to public health stems from co-pollutant reduction. Across Cuyahoga, Lake, and Lorain Counties these reductions will largely occur in LIDAC tracts. As **Table 51** illustrates, the vast majority of co-pollutant reductions will occur in, and be experienced by, LIDACs.

Table 51: Air Quality Co-Benefits from Industry Measures in LIDACs & Non-LIDACs

County	Location of Facility	Tons of SO_2 Reduced	Tons of NO_x Reduced	Tons of VOCs Reduced	Tons of $PM_{2.5}$ Reduced
Cuyahoga	LIDAC	63.8	35.7	16.6	3.9
	Non-LIDAC	45.9	37	4.8	2.1
Lake	LIDAC	0.3	2.1	4.7	0.7
	Non-LIDAC	0	0	0	0
Lorain	LIDAC	54.1	110.8	14.4	12
	Non-LIDAC	0	0	0	0
Medina	LIDAC	0	0	0	0
	Non-LIDAC	0.01	12.6	4.8	0.5
MSA Total	LIDAC %	99%	86%	82%	94%
	Non-LIDAC %	1%	14%	18%	6%

The majority (57%) of the benefits from VMT reduction would also occur in LIDACs, with a range of 0% (Geauga and Medina Counties) to 61% (Cuyahoga County).

9.3.2. Disbenefits of Emissions Reduction Measures on LIDACs

LIDACs will experience both measure-specific and cross-sector co-benefits and disbenefits from measure implementation.

The Benefit Analysis section provided a detailed overview of disbenefits of measures to the MSA. Many of the outlined disbenefits are the same for LIDACs. Here are the specific disbenefits that may have an outsized impact on LIDAC communities.

(1) **Cost-Prohibitive**: Recommended measures will require substantial investments to implement and maintain. For LIDACs this will pose a challenge as the need may far outweigh the available resources, which constrains local governments' ability to invest as required.

(2) **Maintenance and Buy-in for Tree Canopy Restoration:** Tree planting efforts that aim to restore the tree canopy will also impose maintenance costs and require public buy-in. Community members expressed concerns about the poor maintenance of existing trees. Many residents worried that the burden of maintenance would fall on homeowners or create safety hazards with increased frequency of severe storms, which represents a significant disadvantage for residents.

(3) **Increased Property Taxes**: Improvements that result in energy efficiency and lead to the development of high-performance buildings also increase property values. Increased property valuation can result in increased property taxes and can lead to the displacement of marginalized residents.

(4) **Negative Impact on Future Development:** There are potential disbenefits associated with increasing tree canopy in urban neighborhoods. For example, efforts to regreen vacant parcels could delay or prevent future TOD through reduced density needed for frequent public transit. There is also a disbenefit if communities spend critical resources on trees, only to see them cut down later for new development.

(5) **Workforce Displacement:** Job losses, particularly for lower-skilled workers, due to the adoption of new technologies that require unique expertise. If there are no specific training or upskilling programs in place, new technology may displace low-skilled workers. Community members raised job displacement, particularly in places heavily reliant on industry for employment, as a primary concern during engagement sessions.

(6) **Increased Cyclists and Pedestrian Crashes:** Section 8.3 noted that the MSA could see an increase in the number of cyclists and pedestrians injured and killed on the region's roads as people shift away from driving, at least in a worst case scenario. This impact would likely be higher in LIDACs, as Black and Hispanic Americans are roughly two to four times more likely to die while walking and biking than White Americans.[375]

Authority to Implement Emissions Reduction Measures

10. Authority to Implement Emissions Reduction Measures

To analyze local authority to implement emissions reduction measures, it is important to consider how local governments act to influence GHG emissions. Local jurisdiction authority to regulate GHGs comes from broad, general constitutionally derived “police power” or delegated authority under state or federal law. Use of police authority may not conflict with “general” law (e.g., state law) under preemption principles found in state constitutions or federal expressed or implied preemption under the Supremacy Clause of the U.S. Constitution.[376]

Police power of a city or county within its own boundaries is as broad as that of the state legislature and subject only to limitations of general law. Police power must be both:

- Reasonably related to a legitimate government purpose; and
- Have a reasonable tendency to promote public health, morals, safety, or general welfare of the community.[377]

Police power is especially well established in land use law enactment and enforcement. Local governments have both police power and delegated authority from the legislature to establish climate change policies and regulations to reduce GHGs in general plans, CAPs, zoning codes, TOD regulations, carbon sequestration (including urban forestry), energy conservation actions through green building practices and reach codes, water conservation, and solid waste reduction. Land use authority is subject to the vested rights doctrine and Subdivision Map Act that limits how a subsequent change in local law or the authority to impose conditions apply to a particular improvement to land or a vesting tentative map for subdivisions.[378] Local jurisdiction police power is also subject to state preemption. Counties act with more autonomy over governance decisions than common law cities; however, all local jurisdictions are controlled and subject to general state law. Because counties are the legal subdivision of the state, the state may delegate or rescind any delegated function of the state to a county.[379]
Local jurisdictions also act with the authority to tax, issue bonds, and impose fees, charges, and rates.[380] This authority is derived from and limited by the Ohio Constitution and statute, including requiring voter approval for taxes and bonds.

This review of authority will analyze federal and state preemption with regards to local jurisdiction, police power and delegated authority. It will evaluate opportunities for local jurisdictions to act within existing constitutional, legislative, and regulatory frameworks and to identify uncertainty with respect to authority. This review of authority is comprehensive but not exhaustive given the complexity of some of the laws involved and the lack of activities in certain areas such as climate action. Additional work in this area is necessary to understand the opportunities and challenges presented by local policies.[381]

10.1. State and Federal Jurisdiction

Local municipalities in Ohio are granted municipal powers of home rule under Article XVIII, §3 and §7 of the Ohio Constitution. Municipalities have "authority to exercise all powers of local self-government and to adopt and enforce within their limits such local police, sanitary and other similar regulations, as are not in conflict with general laws.[382] When local law conflicts with general law, general (state) law preempts local law, and federal law preempts both in areas of concurrent jurisdiction.

GHG emissions standards are regulated both federally and at the state levels. The federal government sets tailpipe emissions standards, and state and local governments cannot enforce alternative standards. California, however, is permitted to apply for waivers from U.S. EPA under §208 of the Clean Air Act Amendments (CAAA) of 1970. State law preempts local limits on emissions from interstate commerce, aircraft, or rail in Ohio under H.B. 201. Thus, the decarbonization of transportation as outlined in the CAPs of the Cleveland-Elyria MSA are subject to a complex web of concurrent regulations at the state and federal levels. This means that local emissions reduction targets can be difficult to implement.

Local governments in the Cleveland-Elyria MSA can instead use incentives to achieve their targets in the transportation sector. However, local authority can be overruled in cases where city policy is ruled to conflict with the statewide regulatory scheme. In 2015, the Ohio Supreme Court decided *State ex rel. Morrison v. Beck Energy Corp.* The court determined that the home rule amendment to the Ohio Constitution did not grant the city of Munroe Falls the power to enforce its own permitting scheme atop the state system. As such, local permitting systems are unlikely to prevail against state challenges. The same applies to bans on natural gas, which are outright preempted by H.B. 201.[383] The bill also prohibits the restriction of use or sale of a motor vehicle based on the energy source used to power the motor vehicle. Such legislation is directly at odds with the provisions of many CAPs, in which electrification of municipal fleets and public transportation are key tenets.

10.2. Opportunities for Local Policies and Regional Collaboration

Local governments in the Cleveland-Elyria MSA find their ability to implement decarbonization measures constrained by both state and federal law. Accordingly, they are left to indirectly regulate GHG emissions. Jurisdictions can leverage Infrastructure to encourage the transition to EVs. Public utilities are subject to oversight by the Public Utilities Commission of Ohio (PUCO) and must abide by the Public Utility Regulatory Policies Act (PURPA). However, they have significant room to invest in clean energy generation; distribute clean electrons produced by other suppliers; and provide incentives for energy efficiency and electrification. Communities that rely on energy from investor-owned utilities (IOUs), on the other hand, are more constrained by state lawmaking and PUCO regulations, which currently preclude even voluntary energy efficiency incentive programs. Additionally, local governments cannot implement building codes in conflict with those set by the Ohio Board of Building Standards.

Despite legal and regulatory roadblocks, there is room for localities to coordinate with the state and federal government to achieve meaningful decarbonization goals. In the transportation sector, state and federal agencies can provide funding for local municipalities to invest in EV charging and to electrify public fleets. By working together through venues like NOACA, the State of Ohio can support counties and cities to achieve the decarbonization efforts in the transportation sector are most likely to be implemented successfully.

Industrial development policy can be a powerful engine for regional growth if it targets businesses focused on decarbonization, energy efficiency, waste reduction and re-use, green building materials, tree nurseries, and similar materials, technologies or strategies. For example, Ohio offers an incentive program to encourage the installation of solar power. Such incentives include Solar Renewable Energy Certificates (SRECs), which allow residents and businesses to earn credit for each megawatt-hour their PV systems generate. Federal incentives include the Production Tax Credit (PTC) and the Investment Tax Credit (ITC) for clean energy installations, though recent policy changes have significantly limited the availability of these tax credits.[384] These incentives demonstrate how governments can use industrial development policy to decarbonize.[385]

Decarbonization efforts that pertain to electrification, residential and commercial energy, waste and material management, and AFOLU require a reconciliation between state and local policy. Many state agencies such as PUCO preempt any municipal action in these areas. For decarbonization efforts to be successful, state governments must grant decision-making authority to local governments in these areas under the principle of home rule jurisdiction.

Additionally, more regions within the Cleveland-Elyria MSA would have to adopt CAPs. Currently, Geauga, Lake, Lorain, and Medina Counties do not have a CAP. Municipalities within those counties, outside of Oberlin, also do not have CAPs, though Painesville was part of the coalition that secured $129.4 million in CPRG implementation funds. If more municipal and county governments act as first movers to advance climate action, the state legislature may be more inclined to enact policies to support those efforts.

10.3. Opportunities to Expand Local Authority

There are opportunities for local governments within the Cleveland-Elyria MSA to promote policies that expand their ability to implement CCAP measures, particularly at the state level. Collaboration with utilities will meaningfully contribute to decarbonization. Examples include pilot demand response programs for residential buildings and advocacy for State of Ohio policies that enable IOUs to actively participate in and scale such programs.

Between now and 2035, local governments can advocate for the following state policies:

- Legislation to enable community solar, including virtual net metering policies;
- PUCO permission for communities to partner with IOUs to pilot residential demand response programs;
- Restoration and expansion of the state Energy Efficiency Portfolio Standard (EERS) and Advanced Energy Portfolio Standard (AEPS);
- Implementation of Time-of-Use (TOU) pricing structures through IOU rate cases that reward off-peak energy use;
- Roll out smart meters and access real-time energy data through IOU rate cases;

- Promote the development and deployment of VPPs to aggregate distributed energy resources for grid reliability, renewable integration, and emission reduction before both the PUCO and the legislature;
- Encourage PUCO to expand performance-based ratemaking policies for IOUs that encourage cost-effective investments in reliability and resilience, including grid-enhancing technologies (GETs);
- Fully and fairly implement state-operated clean energy and energy efficiency funding programs, including the Greenhouse Gas Reduction Fund (GGRF), Solar for All (SFA), the Home Efficiency Rebates (HOMES) program, and High-Efficiency Electric Home Rebate Act (HEEHRA) program;
- Expand utility assistance and protection programs for residential customers, including the Low-Income Home Energy Assistance Program (LIHEAP), and create utility shutoff protections for customers during the summer months;
- Authorize the expansion of passenger rail within the state;
- Expand ODOT funding for public transit and other forms of sustainable transportation;
- Reduce or eliminate excess vehicle registration taxes for hybrids, plug-in hybrid EVs, and BEVs;
- Explore adoption of VMT-based user fees for transportation infrastructure
- Fully implement NEVI program for public EV charging along highway corridors;
- State support for evaluating priority locations for geologic sequestration of CO_2;
- State regulations to enable and properly regulate geologic sequestration of CO_2; and
- Fully fund programs that promote nature-based solutions, including H2Ohio.

Between now and 2035, local governments can advocate for the following federal policies:

- Protection, restoration, and expansion of existing grants and tax credits that support implementation of CCAP measures;
- Reauthorization of offshore wind farm on Lake Erie;
- Authorization of expansion of nuclear generation at Perry Power Plant from Nuclear Regulatory Commission

For more information on Authority to Implement Emissions Reduction Measures, including entities responsible for measure implementation, please consult the *CCAP Implementation Playbook* and Appendix D.

Intersection with Other Funding Availability

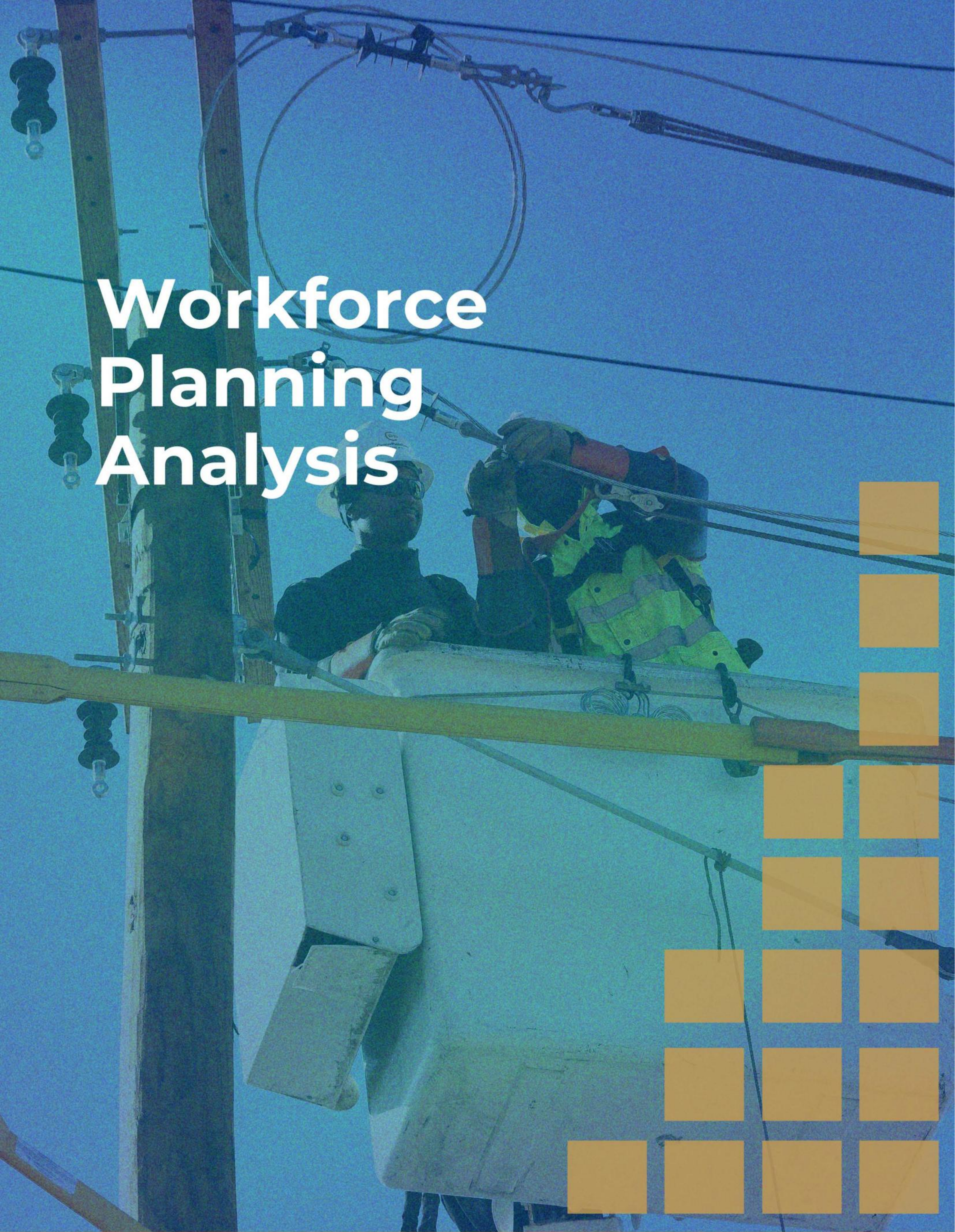
11. Intersection with Other Funding Availability

Through the passage of the IRA and the Infrastructure Investment and Jobs Act (IIJA), the federal government made the largest investment in climate action in history. However, due to changes in policy at the federal level, many of the funding opportunities created and expanded through these bills have been eliminated, rescinded, curtailed, or rendered an uncertain future.

For those reasons, the CCAP focuses on a broader suite of actions and financial mechanisms that communities themselves can take advantage of and have at their disposal, particularly market-based approaches. Communities should strongly consider combined or “stacked” multiple financing mechanisms to increase the viability of any project. For more discussion of funding, review the “How to Pay For It” section in the *CCAP Implementation Playbook.*

For detailed information on the local, state, and federal programs that communities within the Cleveland-Elyria MSA can potentially utilize to fund CCAP measures, consult Appendix D which outlines funding opportunities for each measure and details whether entities within the region have already secured implementation funds.

Workforce Planning Analysis



12. Workforce Planning Analysis

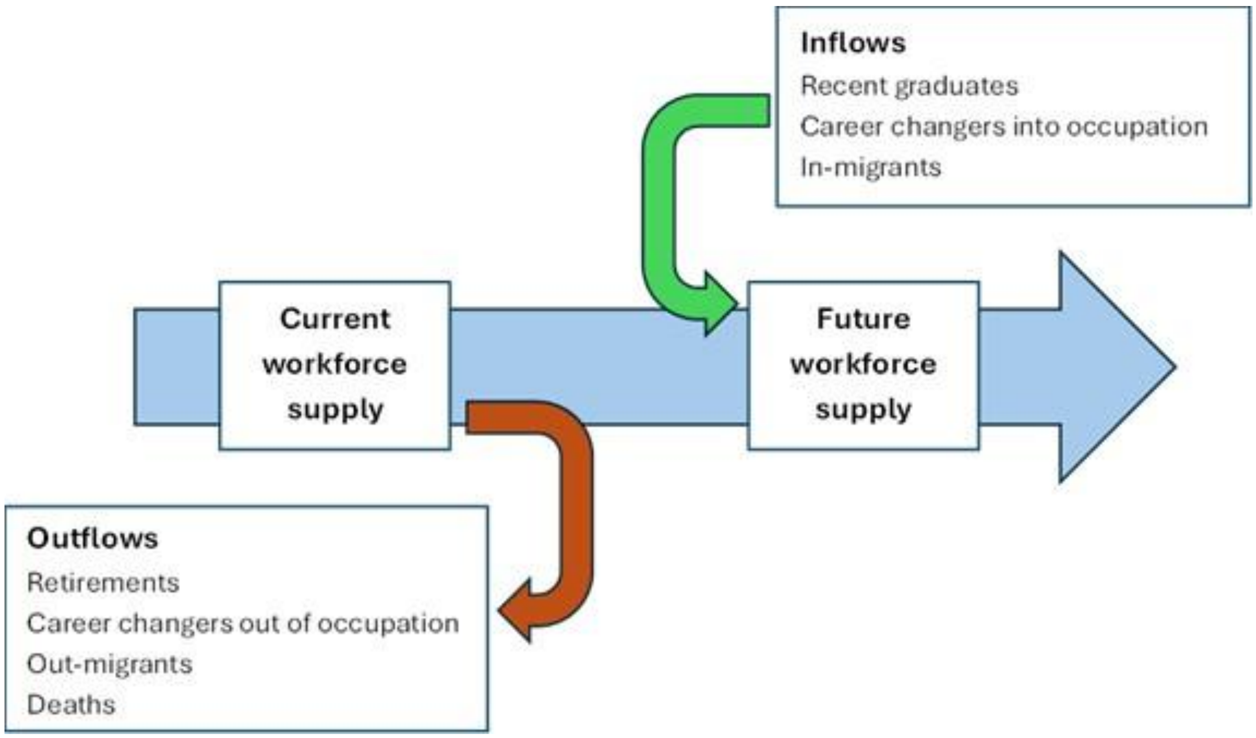
A skilled and adaptable workforce is critical to realize the region's GHG reduction goals. This section outlines potential workforce shortages that could impede implementation of the priority measures identified in this framework. CCAP includes strategies to address potential workforce shortages, including potential partners in this effort. The labor market considered for this analysis is the Cleveland-Elyria MSA. MSAs represent a reasonable approximation of a local labor market, making it the appropriate unit of analysis for this workforce planning process.[386]

For each decarbonization measure, the CRDF team member who proposed the measure also identified occupations needed to implement it. The team then supplemented this list by querying ChatGPT to identify additional occupations relevant to the installation and maintenance of the proposed measure.[387] For example, the AI chatbot inferred that the deployment of utility-scale solar would require a *power line installer*, in addition to the *electrician* and *solar panel installer* roles originally proposed by the CRDF team. CRDF team members validated occupations suggested by ChatGPT against the U.S. Department of Labor's O*NET occupational database.[388] Occupational titles were then mapped to the Standard Occupational Classification (SOC) system, which federal agencies use to categorize workers and organize employment statistics by occupation.

12.1. Workforce Supply Analysis

The CRDF team next used a stock-and-flow model to project the workforce supply in the Cleveland-Elyria MSA for occupations needed to implement GHG reduction measures. U.S. federal agencies and international bodies such as the World Health Organization widely use stock-and-flow models as a straightforward approach to project workforce supply by occupation compared to more complex statistical methods.[389] **Figure 43** provides a conceptual version of the stock-and-flow model used to project workforce supply below.

Figure 43: Stock-and-Flow Model for Workforce Supply Projections[390]



Workforce supply for an occupation depends on the number of workers currently employed in the region, individuals who move into or out of a region, recent graduates of local educational programs; career changers who enter or leave an occupation, and those who exit the workforce entirely (e.g., retirement).

The team obtained data on current occupational employment by SOC code for the Cleveland-Elyria MSA from the Bureau of Labor Statistics (BLS) via its Occupational Employment and Wage Statistics (OEWS) program.[391] In addition to data from the American Community Survey (ACS), the team estimated workforce inflows and outflows through the U.S. Census Bureau's Current Population Survey (CPS) and the U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS).[392] The team estimated labor supply based on the five most recent years of available data.

The team obtained projected workforce demand and expected workforce exits by occupation in the Cleveland-Elyria MSA from the Ohio Department of Jobs and Family Service (ODJFS) through its Occupational Employment Projections.[393] The team based these projections on BLS data, localized to reflect anticipated occupational demand in each of Ohio's MSAs.[394] BLS-based employment projections represent the number of jobs needed to support expected future economic activity.[395]

The team subtracted projected workforce supply from projected workforce demand to assess the risk of shortage in the Cleveland-Elyria MSA for each occupation required to implement GHG reduction priority measures. If projected demand exceeded supply, the team flagged that occupation as having a workforce shortage. Solutions will be necessary to address the regional workforce shortage for such occupations.

Table 52 shows the estimated workforce surplus or shortage for occupations required to implement priority GHG reduction measures in the Cleveland–Elyria MSA. The table compares projected labor supply with projected demand for each occupation and shows both the absolute and percentage differences. Occupations where demand exceeds supply are potential shortage risks, as are occupations with a surplus of less than 5% where minor shifts in demand or attrition could lead to shortfalls.

Table 52: Workforce Surplus and Shortage by Occupation for GHG Reduction Measures in the Cleveland-Elyria MSA

Occupation	2025 Estimated Employment Demand	2025 Estimated Workforce Supply	Shortage or Surplus (Jobs)	Shortage or Surplus (%)	Median Annual Income (2024$)
Forester	20	17	-3	-16.6%	$61,050
Building Inspector	704	607	-97	-13.8%	$66,910
Maintenance Workers, Machinists	262	250	-12	-4.5%	$57,560
Quality Engineer	3,772	3,626	146	3.9%	$98,760
Maintenance Technician	12,438	12,284	-154	-1.2%	$49,390
Electrical Engineer	1,156	1,143	14	-1.2%	$99,330
Electrician	4,714	4,661	-53	-1.1%	$65,630
Truck driver	12,744	12,737	-6	0.0%	$57,090
First-line Supervisors of Mechanics, Installers, and Repairers	3,877	3,910	32	0.8%	$78,210
Electrical Power Line Installer	543	553	10	1.9%	$88,920
Computer Sys. Analyst	3,007	3,073	66	2.2%	$97,190
First-line Supervisors of Construction Trades	3,476	3,565	89	2.6%	$78,090

Occupation	2025 Estimated Employment Demand	2025 Estimated Workforce Supply	Shortage or Surplus (Jobs)	Shortage or Surplus (%)	Median Annual Income (2024$)
Power Plant Operators	30	31	1	2.7%	$66,850
Network and Computer Systems Administrator	3,118	3,218	100	3.2%	$93,080
Nuclear Power Plant Operator	70	72	3	3.6%	$124,030
Power Distributor and Dispatcher	110	114	4	4.0%	$88,480
HVAC Mechanics and Installers	2,540	2,676	136	5.4%	$61,680
Civil Engineer	1,420	1,509	90	6.3%	$85,030
Plumbers, Pipefitters, and Steamfitters	2,789	3,016	226	8.1%	$62,820
Crane Operator	371	403	32	8.7%	$62,460
Architects	661	725	64	9.7%	$87,470
Landscape architects	80	88	8	9.8%	$77,400
Health & Safety Engineer	30	33	3	11.0%	$118,320
Urban Planner	141	162	21	14.9%	$69,700
Sustainability Analyst	4,881	5,631	750	15.4%	$75,770
Solar Photovoltaic Installer	80	94	15	18.2%	$53,640
Cybersecurity Analyst	935	1,125	190	20.3%	$105,990
Wind Turbine Technician	15	24	9	64.4%	$76,960

While solar photovoltaic installers and wind turbine technicians currently show a workforce surplus, both occupations represent a very low employment base in the region. As a result, even modest increases in deployment of utility-scale or distributed renewable energy could quickly shift these occupations into shortage. Given the small size of the current labor pool, regional training and recruitment systems may lack the capacity to respond rapidly to increased demand, particularly if multiple clean energy projects ramp up simultaneously.

12.2. How to Address Workforce Shortages for CCAP Measure Implementation

The next step is to identify targeted strategies to address potential workforce shortages. The goal is to identify actionable solutions and the key partners who can help implement them. This includes efforts to expand training pipelines, attract new entrants, support career transitions, and retain existing workers. The following section outlines potential approaches tailored to specific occupational gaps. The approaches draw on a recent climate sector workforce landscape analysis commissioned by the Cleveland Foundation, which provides a timely foundation to build a broadly shared regional climate workforce development strategy.

12.2.1. Aligning Training Programs with High-Growth Climate Occupations

The region must prioritize training for occupations central to decarbonization and resilience—including electricians, energy auditors, and building envelope specialists. Current training capacity is insufficient to meet projected needs in these and other clean infrastructure roles.

Practical steps:

- Develop short-term, stackable credentials aligned with clean energy certifications (e.g., NABCEP, BPI).
- Incorporate energy efficiency and electrification topics into existing trades and technical curricula.
- Identify and fill gaps in career-oriented training programs for newer occupations such as EV charging infrastructure technicians and heat pump specialists.
- Align course content with employer-defined skill needs through co-developed curricula.

12.2.2. Increase Access to Training and Jobs for Underserved Populations

Barriers such as childcare, transportation, digital access, and prior involvement with the criminal justice system hinder access to good jobs in climate-aligned sectors. Residents of historically disinvested neighborhoods in the Cleveland-Elyria MSA have often faced the greatest challenges in accessing career opportunities.

Practical steps:

- Partner with community-based organizations, such as Towards Employment and the Urban League of Greater Cleveland, to deliver wraparound services.
- Use neighborhood-based outreach and training hubs to improve accessibility.

- Provide stipends and support services (e.g., transit passes, legal aid) for training participants.
- Develop recruitment strategies that target underrepresented populations, with clear metrics for inclusion and access.

12.2.3. Creating a Regional Coordinating Entity for Climate Workforce Development

Workforce and climate planning efforts currently operate in silos. A coordinating body focused on climate-related employment can improve alignment across training providers, employers, and community partners.

Practical steps:

- Form a regional climate workforce working group or expand an existing platform (e.g., sector partnerships).
- Use this group to define occupational priorities, pool resources, and oversee funding strategies.
- Coordinate data collection and labor market analysis to track supply-demand dynamics. Ensure all supported programs are designed to promote inclusive participation and uphold job quality standards.

12.2.4. Engaging Employers in Scalable Workforce Models

Employers—particularly in the construction and clean energy sectors—often struggle to engage in training due to resource constraints or administrative burden. Broader employer participation is critical to create placement opportunities and align training to real demand.

Practical steps:

- Offer technical assistance to help small and mid-sized firms participate in apprenticeships or internship programs.
- Develop shared training consortia for high-demand occupations like solar installation and energy retrofits.
- Create regional hiring collaboratives where employers pool entry-level openings and commit to hiring from cohort training models.
- Design flexible onboarding supports that help firms retain early-career workers.

12.2.5. Integrating Workforce Outcomes into Public and Philanthropic Investments

Climate and infrastructure investments create a window of opportunity to link capital deployment with job creation. Workforce development goals should be embedded directly into funding, procurement, and program design.

Practical steps:

- Include workforce partnership requirements in local government and foundation-funded clean energy projects.

- Require bidders to demonstrate connections with local training programs and a plan for inclusive hiring.
- Use community benefit agreements or project labor agreements to formalize labor standards and ensure broad community access to opportunities.
- Track outcomes by demographic, zip code, and job quality metrics.

12.2.6. Piloting and Scaling Sector-Based Training Programs

Targeted pilot programs can address urgent workforce shortages and test scalable models. Programs should prioritize clear pathways into occupations, employer commitment to hiring, and ongoing worker support.

<u>Practical steps</u>:

- Launch cohort-based training in solar, building electrification, and energy efficiency, with direct employer input.
- Involve workforce intermediaries such as Towards Employment or Manufacturing Works in recruitment and placement.
- Build-in retention strategies (e.g., mentorship, wage subsidies, follow-up services) to ensure job sustainability.
- Evaluate pilot programs for effectiveness and scalability using shared regional metrics.

The Cleveland-Elyria MSA has a foundational workforce infrastructure and engaged ecosystem partners. However, without better alignment and stronger employer integration, the region may be unable to meet its clean energy workforce needs. A regional workforce strategy grounded in these practical steps can ensure climate investments translate into durable, high-quality jobs across the region.

Conclusion

13. Conclusion

CCAP implementation to achieve the Cleveland-Elyria MSA's ambitious climate targets will require concerted, ongoing work by each of the MSA's five counties and 164 communities, across all sectors of the economy, and by actors of all types, including residents, businesses, community groups, schools, and government agencies. The actions outlined in this plan will reshape many of the ways that we produce and consume energy within the MSA, but this shift will also provide significant benefits for people across the region.

As Chapter 4 illustrates, climate change presents a clear and present threat to the Cleveland-Elyria MSA, and people across the region already feel these impacts. From the wildfire smoke that blanketed the region in June 2023 to the dangerous heat waves in June 2024 and June 2025 to the devastating tornadoes that knocked out power for 400,000 people in August 2024, climate change is no longer distant in time or space. Its effects are already here and will compound if we do not act decisively to address this challenge.

Chapters 8 and 9 demonstrate that climate action represents an unprecedented opportunity to envision a new future in which the Cleveland-Elyria MSA is a vibrant region with abundant resources – economic, human, natural, and social – that form the foundation for long-term, sustainable success. The Cleveland-Elyria MSA is better positioned than many other MSAs to succeed in the coming decades, but that future is not foretold. The decisions that we make over the next five years can place the region on this path to success, and this CCAP provides a detailed map to that destination.

There is no one-size-fits-all approach to climate action, and what makes sense for Legacy Cities will not necessarily make sense for Outer Ring Suburbs or Rural Communities. This CCAP and the accompanying *CCAP Implementation Playbook* outline strategies that are accessible for all communities. Community leaders can choose measures that best address their unique needs and respond to their specific conditions. Nevertheless, the CCAP includes six "Go Big" Strategies for the MSA that will put the region at the forefront of climate action and make it competitive throughout the Great Lakes and across the country. These are:

1. Expanding Nuclear Generation at Perry Nuclear Power Plant
2. Developing Offshore Wind on Lake Erie
3. Net Zero Steelmaking at Cleveland-Cliffs
4. Expanding Passenger Rail and Light-Rail Service
5. Developing a Regional Direct Air Capture (DAC) Facility to remove carbon from the atmosphere
6. Implementing a "Headwaters Forests Initiative" to reforest 10 square miles of the region's headwaters

These "Go Big" Strategies and the other measures in this CCAP will not be easy or cheap, and actors at all levels may try to delay action. However, the costs of inaction are substantial and get bigger by the day, and the benefits of action outweigh the costs significantly. Just as Mayor Stokes realized over 50 years ago, Northeast Ohio's common environmental, economic, and social challenges are intertwined. This CCAP can provide a guide for the Cleveland-Elyria MSA to become "almost legendary" again, this time as a climate leader.

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CCAP Materials can be found here:

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