NOACA
Northeast Ohio Areawide Coordinating Agency

DRAFT Cleveland-Elyria Metropolitan Statistical Area Comprehensive Climate Action Plan

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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
- Greenhouse Gas Reduction Fund (GGRF)
- GHG: Greenhouse Gas
- GHGRP: Greenhouse Gas Reporting Program
- GO Bond: General Obligation Bonds
- 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
- HEEHRA: High-Efficiency Electric Home Rebate Act Program
- HFCs: Hydrofluorocarbons
- HOMES: Home Efficiency Rebates Program

- HVAC: Heating, ventilation, and air conditioning
- IACs: Industrial Assessment Centers
- ICEVs: Internal Combustion Engine Vehicles
- ICLEI USA: Local Governments for Sustainability USA
- IEA: International Energy Agency
- IHSC: The Industrial Heartland Solar Coalition
- IIJA: Infrastructure Investment and Jobs Act
- IOUs: Investor-Owned Utilities
- IPCC: Intergovernmental Panel on Climate Change
- IPPU: Industrial Processes and Product Use
- IRA: Inflation Reduction Act
- ITC: Investment Tax Credits
- JCRP: Joel Ratner Community Partnership
- KSU: Kent State University
- KW: Kilowatts
- Lbs/MWh: pounds per megawatt hour
- LCA: Life Cycle Analysis
- LIHEAP Low-Income Energy Assistance Program
- LDVs: Light-Duty Vehicles
- LEED: Leadership in Energy and Environmental Design
- LIDAC: Low-Income and Disadvantaged Communities
- 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
- MTCO2e: metric tons of CO2 equivalent emissions
- MT/Day: Metric ton per day
- 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
- NO_x: Nitrogen Oxides
- NOACA: Northeast Ohio Areawide Coordinating Agency
- NOPEC: Northeast Ohio Public Energy Council
- 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
- Solar for All (SFA)
- SDSN: Sustainable Development Solutions Network
- SI: EJScreen Supplemental Index
- SO_2: Sulfur Dioxide
- SOC: Soil organic carbon
- SOEs: Solid Oxide Electrolyzers
- SOPEC: Sustainable Ohio Public Energy Council
- SOV: Single Occupant Vehicle
- SPA: Statistical Planning Area (City of Cleveland)
- SUN: Solar United Neighbors
- TCO: Total Cost of Ownership
- TDM: Transportation Demand Management
- TOD: Transit Oriented Development
- TOU: Time-of-Use pricing
- TW: Terawatts
- UHI: Urban Heat Island
- U.S. EIA: U.S. Energy Information Administration
- U.S. EPA: U.S. Environmental Protection Agency
- UNEP: United Nations Environment Programme
- USDA: U.S. Department of Agriculture
- USGBC: U.S. Green Building Council
- VMT: Vehicle Miles Traveled
- VOCs: Volatile Organic Compounds
- VPP: Virtual Power Plant
- VRU: Vulnerable Road User
- WRLC: Western Reserve Land Conservancy
- ZEVs: Zero Emissions Vehicles

Executive Summary

This Comprehensive Climate Action Plan (CCAP) for the Cleveland-Elyria Metropolitan Statistical Area (MSA) includes a discussion of how the climate is already changing in and the expected changes through 2050; a review of greenhouse gas (GHG) emissions by sector and the measures the MSA can take to lower those emissions by 2050; a plan to help communities across the MSA implement these measures; and additional technical appendices.

Background

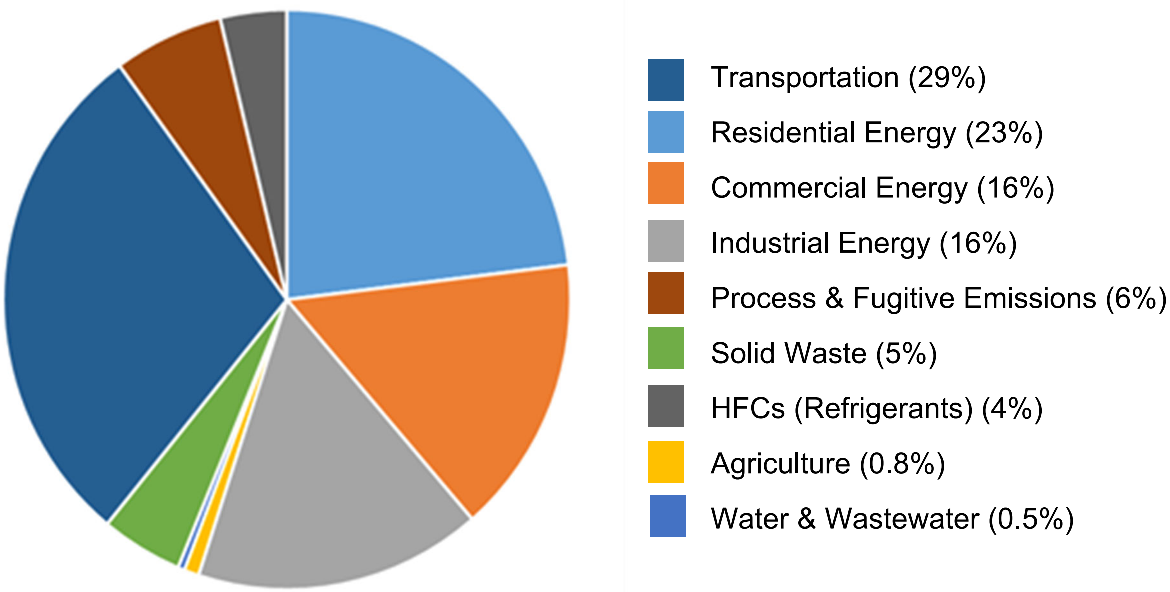
While climate pollutants like carbon dioxide (CO_2) and methane (CH_4) have long been a part of our atmosphere, current levels are much higher than at any point in human history. This extra carbon is acting like a blanket, warming the planet more than in the past. Temperatures are already rising: 2023 and 2024 were the hottest years on record, and the last decade was the hottest on record. If the planet warms by more than 1.5°C from historical levels, this extra warmth will upset many systems that we rely on, threatening our food and water supplies and leading to extreme weather events and other risks. To lower this risk, the Cleveland-Elyria MSA must reduce our climate pollution rapidly to reach net zero. Communities in the MSA produce significant amounts of climate pollution, and we must act with urgency to address this crisis.

Target Audience

The target audience for this CCAP is the community leaders, both elected and administrative, of the 164 cities, villages, and townships within the MSA; leaders of the MSA's five counties; and large public organizations. Local governments are the best starting point for this climate action strategy. Individuals interact most often with their local governments, allowing for better communication and feedback on this work. Many of the strategies in this CCAP are within the control of local governments, and residents tend to have more trust in local government bodies.[1]

This CCAP outlines strategies that are accessible for all communities, no matter where they are on the path to decarbonization. It builds upon the existing work of the region's climate leaders, while providing on-ramps for communities that are beginning their journeys. Not all of the measures in this CCAP apply to every community, and leaders should choose the measures that best address their unique needs. The CCAP discusses the costs, benefits, and co-benefits of actions, such as improved air quality, cost savings, job creation, and improved resilience, which will help communities consider their options.

Figure 1: 2022 GHG Emissions by Sector, Cleveland-Elyria MSA



Key Takeaways

Decarbonization is already happening

The Cleveland-Elyria MSA has already taken key steps towards decarbonization. This progress can push the region towards certain technologies, policies, or strategies; such as:

Electric Sector: Perry Nuclear Power Plant in Lake County is a unique asset, and it supports efforts to decarbonize the electricity supply. Perry has the capacity to expand, giving the region an advantage in selecting nuclear power as part of its decarbonization strategy.

Transportation Sector: The MSA has begun the shift towards battery electric vehicles (BEVs), and they are the future of transportation across most of the region.

Agriculture, Forestry and other Land Uses (AFOLU): Thanks to the leadership of organizations and assets like the region's Metroparks, the Cuyahoga Valley National Park (CVNP), and Western Reserve Land Conservancy (WRLC), the MSA has incredible capacity to preserve and expand our forest area and invest in other nature-based solutions (NBS).

Organization: Several communities are already on the path to decarbonization. Municipal utilities in the MSA, including Cleveland Public Power (CPP) and Painesville Municipal Electric, produce and deliver clean electricity to residents and businesses. Communities have created sustainability offices to take action on climate. This initial progress provides a vital foundation upon which to build. Some communities have taken additional steps towards decarbonization, such as building district geothermal energy and developing more bikeable and walkable communities. Communities should review their existing efforts and consider how CCAP measures align with this work.

Real Challenges Remain

Lack of consensus: Support for decarbonization is uneven across the region. Several communities have robust efforts, but this work tends to end at city or township limits. Key regional organizations say sustainability is a priority, but there not been a clear commitment from business leaders to decarbonize their operations. This lack of consensus makes regional or multi-community approaches difficult.

Hard to decarbonize industries: Manufacturers like Cleveland-Cliffs make up a large share of climate pollution emissions in the MSA, and it will require significant resources to decarbonize their operations. This CCAP identifies options for these industries, such as adopting new technologies and investing in carbon capture, sequestration, and utilization (CCUS).

Car-dependent communities: The MSA's transportation network is built for a much larger population, making it relatively easy to drive from one place to another. Communities need to use a variety of tools to lower vehicle miles traveled (VMT), like pricing parking.

Old housing and building stock: The MSA is home to large numbers of aging buildings and poor quality houses. Communities face the difficult and expensive choice to demolish these buildings or renovate them.

Increasing building energy needs: As the climate becomes warmer and wetter, it will increase the demand for energy for air conditioning, and this additional demand will more than offset any savings from lower demand for heating during the winter.

Low-cost natural gas: Low natural gas prices reduce incentives to shift to clean energy. These low prices create effects throughout the economy and serve as a barrier to climate action.

Increasing extreme weather (Chapter 4): The MSA is facing more extreme heat and rainfall, and it still experiences extreme cold. As the wildfire smoke events of June 2023 show, extreme events in other regions can also take a major toll on the MSA.

How to pay for it (Chapter 11): Decarbonization requires significant investment in infrastructure, which is expensive. With the loss of funding from the federal government and limited assistance at the state level, it is unclear how much the region can depend on outside support. Tax bases for many communities in the MSA are also flat or shrinking, making it difficult to find local resources to fund climate action.

Solutions for LIDAC Communities (Chapter 9): Resources for climate action are particularly limited for low-income and disadvantaged communities (LIDAC). This report considers the distinct characteristics and needs of these communities and outlines the steps necessary for them to decarbonize. The report also evaluates opportunities where counties and other jurisdictions may adopt regional strategies that benefit LIDACs. Without careful input and planning, something being done *for* a community can become something done *to* a community.

The many risks of inaction (Chapter 5): Choosing not to address this challenge poses significant risks to the region. If the MSA fails to act, it will leave community members vulnerable not only to the changing climate, but also to losing out on the economic and job creation opportunities that will accompany this transition. If the region's leaders do not act, others may step in to fill the gap (e.g. another Great Lakes port city may develop offshore wind).

Market response to technologies: While many technologies already exist that are as good as or better as fossil fuel-based options, others are still needed. This report focuses on the most promising technologies, while recognizing that some may fall short due to market factors.

Where to Start?

Leadership and Vision: Net zero by 2050 is impossible without leadership, as the market will not meet this goal on its own. Climate action requires leadership, planning, vision, and the commitment of community resources. Visions can unify and inspire communities to act by providing a clear picture of the goal people are working to achieve.

Committed Partnerships: Shifting the MSA to net zero emissions will be a huge effort. No community can reach this target on its own. Partnerships let communities combine their resources, engage a larger number of stakeholders, and bring the broader community together. Communities should look to the public, non-profit, and private sector for climate action partners. In the short-term, some communities may want to focus on working with a smaller set of key stakeholders that are already working on this challenge, as it can help them make progress towards 2030 targets and build momentum for broader-based, long-term action.

Durable Community Relationships: Successful climate action requires developing real relationships with communities through regular exchanges in trusted environments and with trusted representatives. This approach can build mutual trust create ways to share information.

Change Behavior, Adopt Principles, and Set Examples: Participants in CCAP engagement sessions often named schools as a priority. School buildings represent an ideal and visible setting to model how energy efficiency and clean energy can provide community benefits. Transforming our schools into climate leaders, with green buildings, sustainable coursework, and clean transportation systems, is a great way to influence public opinion and behavior.

Develop Multi-Sector Strategies: Implementing climate action on a sector-by-sector basis is not the best approach, as there are key links across different parts of the economy. Industrial development policies that targets businesses focused on decarbonization, energy efficiency, waste reduction and re-use, green building materials, tree nurseries, and the like is important for implementing the measures in this report. These businesses can also power growth for the region and its communities. EcoVillages, such as The Oberlin Project and the EcoDistrict in Cleveland's Slavic Village neighborhood, can build civic pride for residents, helping them identify as a "green community." Organizations like landbanks and land conservancy groups can help combined pieces of land for developments, nature-based solutions, and clean energy.

Benchmark and Measure: Communities across the Cleveland-Elyria MSA are at different steps of their decarbonization journey. Developing inventories of GHG emissions and regularly measuring emissions reductions are crucial to guiding the implementation of this CCAP. Subject matter experts across the MSA area available to provide support.

Sector-by-Sector Decarbonization

Electricity (Chapter 7.2): Changing how we produce and deliver electricity is central to this CCAP. Eliminating climate pollution in this sector requires improved energy efficiency, reducing electric grid losses, electrifying systems, and decarbonizing the electricity supply. The MSA's current energy system is massive, and it requires major investment. Demand for electricity is already growing from data centers and new manufacturers, but communities can take important steps to decarbonize the electric sector now. These include enrolling in community choice aggregation (CCA), modernizing distribution grids, adopting strong energy efficiency measures, and developing solar and battery storage on rooftops and in parking lots. New or improved technologies, such as new nuclear, enhanced geothermal, offshore wind, and district geothermal heating/cooling have the potential to accelerate these efforts in the coming years.

Residential & Commercial Energy (Chapter 7.3): The residential and commercial energy sector is both a major challenge and opportunity for climate action. Reducing emissions from this sector will require reducing energy use and embodied carbon in new construction, while upgrading the aging buildings with insulation, air sealing, electrification, and enforcing building codes. Strategies must prioritize underserved communities by integrating affordability, health, and access to essential services. Policy solutions, such as green zoning, electrification incentives, expanded green bank offerings, and workforce development programs are important. Implementing measures in this sector will require a coordinated, data-driven approach to help underserved communities and engage stakeholders.

Industrial Energy and Industrial Process & Product Use (IPPU) (Chapter 7.4): Given the MSA's historical reliance on manufacturing, industry is a critical target for decarbonization. This sector is complex, and it will require solutions that are tailored to each process and facility. Policymakers need to work together with industry to understand needs, identify solutions, and chart pathways to cut emissions. Combining energy efficiency, process efficiency, electrification, onsite clean energy, fuel switching, and carbon capture can put the sector on a path to net zero.

Transportation and Mobile Sources (Chapter 7.5): Decarbonizing transportation requires reducing VMT and shifting to zero-emissions vehicles (ZEVs). The Cleveland-Elyria MSA must invest in public transit and active transportation and by focusing on developing along existing public transit corridors. The region will simultaneously shift towards the ZEVs, including BEVs, hydrogen fuel cell vehicles (FCVs), and low-carbon fuels. This work requires building out vehicle charging and fueling infrastructure, innovative funding approaches, coordinated cross-jurisdictional policies, and partnerships with anchor institutions. These measures will cut climate pollution, improve mobility for all residents, create more vibrant communities, strengthen connectivity, and provide clear benefits to air quality and public health.

Waste & Material Management (Chapter 7.6): Climate pollution in this sector comes from the breakdown of solid waste and wastewater and the use of hydrofluorocarbons (HFCs) for refrigeration. This sector can decarbonize by using systems to capture waste gases, capturing carbon after incinerating waste, and increasing the use of climate-friendly refrigerants. Local governments can encourage circular economies and the reduction of landfilled waste through recycling and composting programs, education and outreach, upgrading existing facilities, and seeking partnerships with groups and industries that use recycled materials.

Agriculture, Forestry, and Other Land Uses (AFOLU) (Chapter 7.7): This sector presents an opportunity to capture and store carbon through reforestation, wetland restoration, and innovative zoning approaches. These measures will provide significant benefits, including reducing urban heat, improving air quality, lowering flood risk, and increasing climate resilience. Urban areas can take advantage of vacant lots, green infrastructure investments, and brownfield redevelopment, while suburbs can implement conservation subdivisions and lawn conversion programs. Rural communities can strengthen agricultural zoning and encourage regenerative farming practices.

Workforce Analysis

Decarbonization will provide new opportunities for workers to grow and thrive. For every fossil fuel-related job lost, this green transition can create two new jobs that provide family-sustaining wages for skilled workers.[2] The region must act to avoid a shortage of workers with the skills required to build, operate, and manage this transition, while ensuring that marginalized groups are not left behind in the process. Specific occupations that will be needed in greater numbers to implement the actions recommended in this regional decarbonization framework include automotive service technicians to maintain EVs and trained electricians and HVAC technicians to facilitate building electrification. Workers across sectors will also need to improve their electrical literacy to promote broad-based electrification (See Chapter 12).

Go Big Strategies

While the CCAP identifies more than 60 emissions reduction measures, there are six, key “Go Big Strategies” that will have significant economic impact and have the potential to drive new growth for our region.

These six approaches can transform the Cleveland-Elyria MSA into a thriving green region on a blue lake.

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

The Cleveland-Elyria MSA stands at a crossroads. The region has seen little to no growth for nearly 75 years, pushing communities within the MSA to compete with one other for business and residential development. The climate crisis presents an enormous threat to the people and systems within the MSA, as it upends the trends we have all come to expect. But the region’s relatively moderate climate, abundant freshwater resources, low cost of living, extensive built environment, and historical manufacturing base also form a strong foundation upon which we can develop as a global leader on decarbonization. This CCAP is a roadmap to guide the Cleveland-Elyria MSA to a future where it is a thriving, resilient green region on a blue lake.

1. Introduction

1.1. Climate Pollution Reduction Grant Overview

Climate change is here. According to the *Fifth National Climate Assessment* (NCA5), a Congressionally-mandated report that evaluates the impacts of a changing climate on the U.S., the evidence that the climate is changing is “incontrovertible,” and “the science is unequivocal” that the addition of GHGs to the atmosphere by humans is driving these trends.[3] Every region of the country is already feeling the impacts of climate change, as 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, drought and heavy precipitation have become more common, and sea level rise poses a serious threat to coastal regions.[4]

While the impacts of climate change are already occurring, the future is not predetermined. If we fail to act, the impacts will become worse, 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.”[5]

Congress has acknowledged the threat of a changing climate and taken steps to reduce it. The Inflation Reduction Act (IRA) provided an array of tools to help place the country on the path towards net zero emissions of GHGs by 2050. One of these tools is the Climate Pollution Reduction Grants (CPRG) program. Section 60114 of the IRA appropriated $5 billion to U.S. EPA to help states, territories, municipalities, tribes, and similar groups in their development and implementation of plans to reduce emissions of climate pollution.

The program divided funding into three tranches:

- CPRG Planning Grants ($250 million) for eligible entities to develop emissions reduction plans;
- CPRG Implementation Grants ($4.6075 billion) for the implementation of measures identified in emissions reduction plans; and
- Administrative costs ($142.5 million).

According to U.S. EPA, the Agency identified three main objectives for the CPRG program:[6]

- Tackling climate pollution while also supporting the creation of good jobs and lowering energy costs for Americans;
- Accelerating work to address unequal exposure to environmental harms and to empower communities to address these disparities; and
- Delivering cleaner air by reducing emissions of harmful air pollutants.

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 deliverable, the Priority Climate Action Plan (PCAP), which it developed in close partnership with the City of Cleveland, in February 2024.[7] 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 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, during 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 by incorporating updated information on GHG emissions in the region, establishing regional emissions reduction targets, identifying a full suite of emissions reduction measures across all significant GHG emissions sources, assessing the benefits of these actions to the MSA, and providing a workforce development assessment for the MSA.

The PCAP, in turn, built off of 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 that would inventory both mobile and stationary sources of GHG emissions and develop both mitigation (reduce emissions) and adaptation (build resilience to climate change) strategies. NOACA committed to emulate this model and completed both a published a GHG emissions inventory (2022) and a draft 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 Cleveland-Elyria MSA. A number of communities and key organizations have developed Climate Action Plans (CAPs). The City of Oberlin was on the leading edge of this work, as it initiated its climate planning work in 2007 and adopted its first CAP in 2011; it has updated that CAP 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. Since that point, Cleveland has updated its CAP in 2018 and 2025; became the first Ohio city to pledge to achieve 100% clean energy by 2050 through its *Clean and Equitable Energy Report*, which it adopted in 2021; 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, including 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 indicated that CCAPs must contain the following elements:[8]

- A GHG inventory;
- GHG emissions projections;
- GHG reduction targets;
- Quantified GHG reduction measures;
- A benefits analysis for the full geographic scope and population covered by the plan;
- A low-income and disadvantaged communities (LIDAC) benefits analysis;
- A review of authority to implement;
- A plan to leverage other federal funding; and,
- A workforce planning analysis.

This CCAP document addresses each of these required elements by building upon and enhancing the PCAP. It includes a GHG inventory (Chapter 2), GHG emissions projections (Chapter 6), priority emissions reduction measures (Chapter 7), an MSA-wide benefits analysis (Chapter 8), a LIDAC benefits analysis (Chapter 9), a review of authority to implement measures (Chapter 10). Where appropriate, this CCAP directly aligns with and incorporates the PCAP elements, such as the business as usual (BAU) scenario and the types of priority emissions reductions measures. Wherever possible, the CCAP expands upon the PCAP by incorporating new data, such as an updated 2022 GHG inventory, expanding upon PCAP content, such as the LIDAC benefits, and incorporating new elements, including emissions reduction targets (Chapter 3) 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).[9] 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 technical analysis for the CCAP.

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

Many natural and human-made processes use carbon from the atmosphere. Trees, for example, take in CO_2 from the atmosphere and use that carbon to build their trunk and branches. The Cleveland-Elyria MSA is working to eliminate all GHG emissions by 2050; however, the most important target is for the MSA to reach net zero, where natural and human-made uptake of carbon must equal carbon emissions. Since natural systems capture carbon slowly, and current man-made systems are very expensive, capturing carbon is a small but necessary part of the solution.

Table 1: Principles of Decarbonization

Decarbonization Principle	Description
Use Energy More Efficiently	Low Cost - Short term 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.

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.[10] 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 inventory, will be 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.[11] The five counties in the MSA include 61 cities, 45 villages, and 58 townships that are home to just under 2.08 million people.[12] The MSA's population has remained fairly consistent over the past several decades, though 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.[13] 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. Nevertheless, population growth within the MSA is largely concentrated outside of Cuyahoga County. From 2013-2017 to 2018-2022, the populations of Geauga (1.6%), Lake (1.1%), Lorain (2.5%), and Medina (3.2%) Counties all increased, while Cuyahoga County's population declined slightly.[14]

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

Just under three-quarters (74%) of the MSA's residents identified as white in the 2020 Census, with one in five identifying as Black or African American, and approximately 2% identifying each as Asian, two or more races, or some other race.[15] Demographics differ within the region; non-white population ranges from a low of 3% in Geauga County to a high of 36% in Cuyahoga County. Approximately 6% of the Cleveland-Elyria MSA identifies as Hispanic or Latino, with a low of 2% in Geauga County to a high of 11% in Lorain County.[16] The median age of Cleveland-Elyria MSA residents is approximately 43.3 years; this is 4.5 years older than the nation as a whole, which shows the aging of the MSA. Nearly one in five residents (19%) is age 65 or over, which is also higher than the national average (17%).[17] As the region's population has remained steady over the past few decades, international migration has been the primary source of population growth for many communities. From 2013-2017 to 2018-2022, nearly 6,100 international migrants moved into the Cleveland-Elyria MSA, accounting for 36% of total population growth within the region.[18] Immigration has been even more important to the urban core, as international migrants represented the only source of population growth within 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.[19] While the region's economy has recovered since the Great Recession, the Cleveland-Elyria MA still has fewer jobs than it did in 2000. Much like population, employment in the MSA 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.[20] 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).

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.[21] 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.[22] 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 developed a six-part typology of communities within Northeast Ohio.[23] This CCAP employs 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 – which span from zero residents per square mile in rural areas to more than 9,000 in Cleveland and Lakewood – 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 will be 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 Developing the CCAP

The development of this CCAP began immediately after the publication of the PCAP on February 28, 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. It developed the project management plan that guided the completion of the CCAP, created the scope of work that defined the responsibilities of the Cleveland Regional Decarbonization Framework (CRDF) team, coordinated regularly with the CCAP partners and CRDF team, managed the execution of CCAP elements, and coordinated the drafting of the plan. 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 led the completion of required CCAP elements.

The City completed the 2022 Cleveland-Elyria MSA GHG inventory during summer-fall 2024, which is discussed in Chapter 2. MOS staff followed the same methodology that NOACA and ICLEI USA employed from the 2018 GHG inventory to complete an update for 2022 and draft an inventory report that included an analysis of changes and trends from 2018 to 2022. MOS then used these updated emissions data to develop proposed emissions reduction targets, as outlined in 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, as outlined in the next section. In addition, Cleveland worked with a number of 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 in Chapter 12.

1.5.2. NOACA

As the CPRG lead organization, NOACA played a central role in managing the CPRG planning grant and guiding the completion of this CCAP. NOACA staff provided overarching guidance and project management for CPRG, including managing regular coordination meetings among CCAP partners and between CCAP partners and U.S. EPA. NOACA worked closely with the City of Cleveland to complete the 2022 Cleveland-Elyria MSA GHG Inventory and to develop regional emissions reduction targets. Furthermore, NOACA led public engagement efforts in Geauga, Lake, Lorain, and Medina Counties 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 the County, excepting 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 stakeholder engagement and outreach, an updated Cuyahoga County GHG inventory, and workforce analysis. 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. Cuyahoga County also worked with the City of Cleveland to create an updated 2022 GHG inventory for the County, which directly supported the completion of the 2022 Cleveland-Elyria MSA GHG inventory, and worked with the City of Cleveland and other partners to deliver the Climate Workforce Assessment and Development report.

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 deliver the execution of a number of required CCAP elements, as outlined in a scope of work. CWRU partnered with researchers and staff from CSU and KSU to complete this work. Based on the scope of work, the CRDF team formed a number of 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 teams.

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, which is outlined in 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, ensuring that these measures aligned with the PCAP and other CAPs from across the MSA, including the 2025 CAP updates from the 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 as a whole, which is detailed in 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.

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 critical to ultimate buy-in from LIDAC stakeholders and 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 partners' 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 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 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 as a whole (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-Futon, Downtown, and Union-Miles neighborhoods. 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, a majority (56%) of participants in these sessions were residents of LIDAC areas.

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 goals and actions that may make it into the CAP; and rank factors that 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 of the more common themes:

- Increase 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) community roundtables in LIDACs, especially those 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 amongst participants. Responses showed the event created new connections amongst 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? What was it about your interactions that helped shift your perspectives or approach?

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

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 of its 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 collaborating 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. 11 of those events were in Equity Zones as designated by Cuyahoga County Planning Commission. The County Sustainability Department tracks the number of people actively engaged with its efforts (2,799 people actively 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.

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

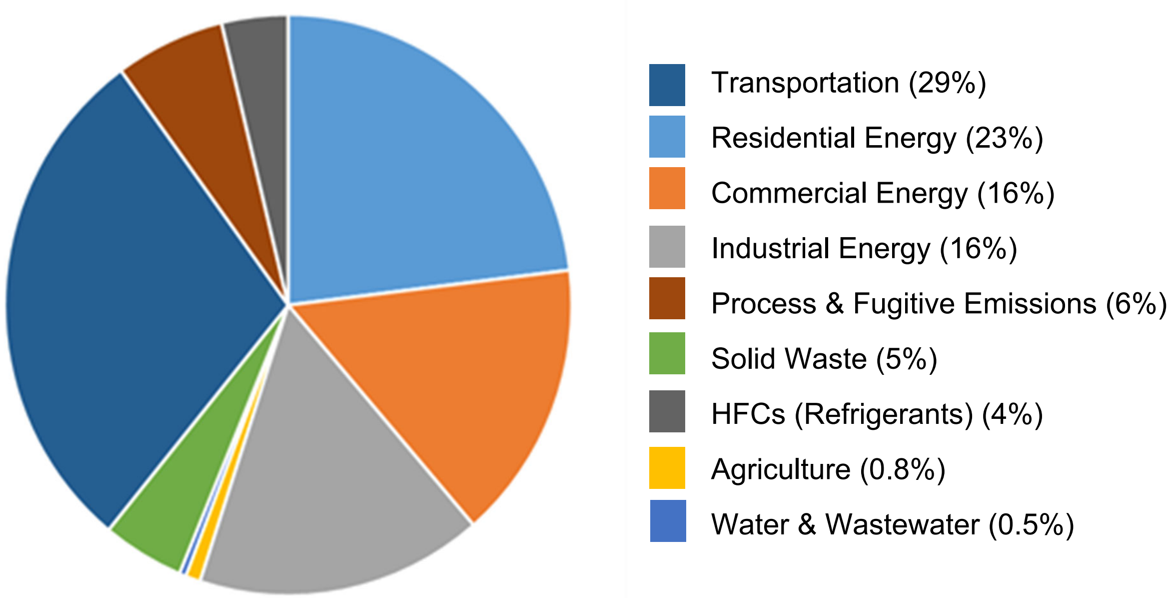
2.1. Inventory Overview

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 2, 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.[24] 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 2: 2022 Total Regional GHG Emissions by Sector



2.2. Inventory Methodology

The first step toward achieving tangible GHG emission reductions requires identifying baseline emissions levels and sources and activities generating 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 3). For example, data on commercial energy use by the community include energy consumed by municipal buildings, and community VMT estimates include miles driven by municipal fleet vehicles.

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.

Figure 3: Relationship of Regional and Government Operations Emissions Inventories

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 in the 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.[25] 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.[26]

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
	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

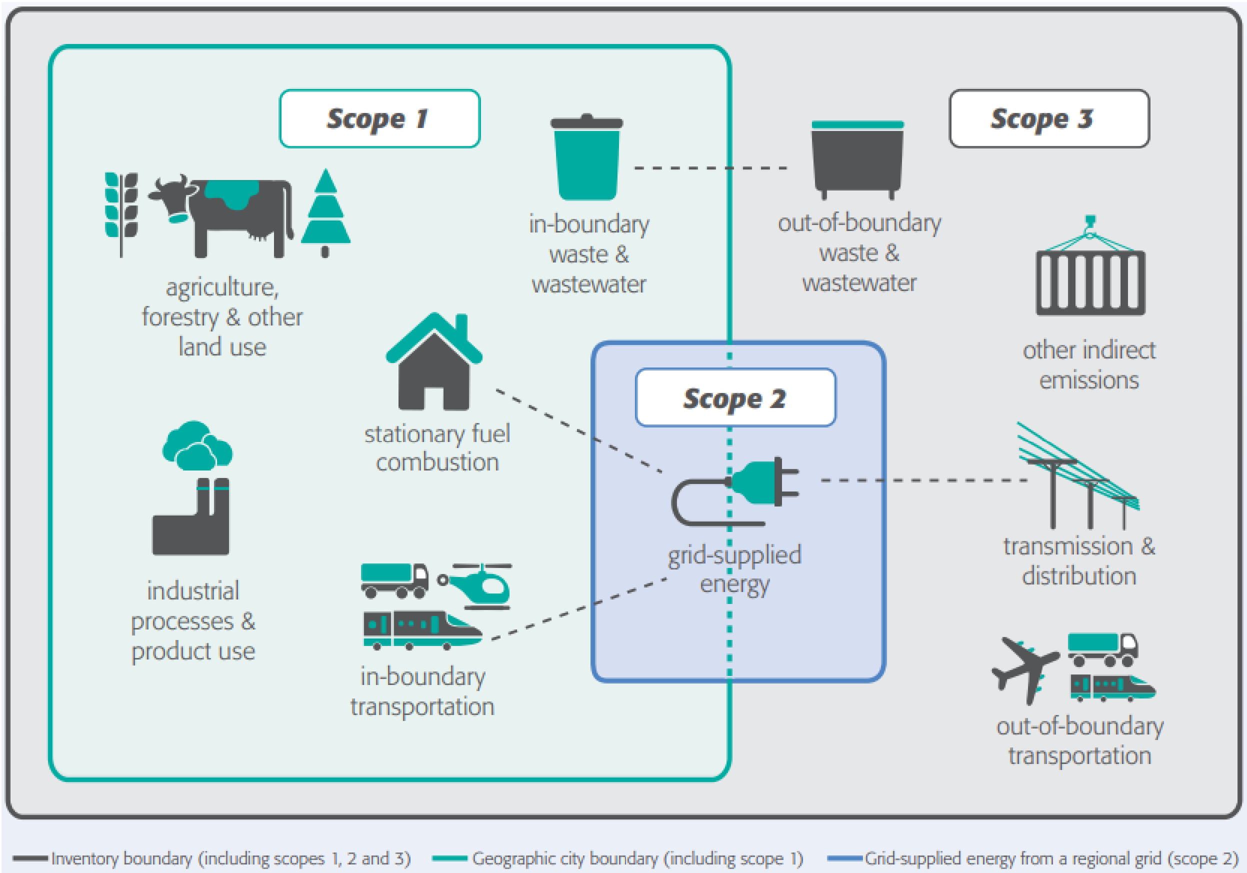
Communities contribute to greenhouse gas emissions in many ways. As Table 7 explains, there are two main categorizations of emissions in a community inventory: 1) GHG emissions that are produced by "sources" located within the community boundary, and 2) GHG emissions produced as a consequence of community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

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

Source	Activity
Any physical process inside the jurisdictional boundary that releases GHG emissions into the atmosphere	The use of energy, materials, and/or services by members of the community that result in the creation of GHG emissions.

Local governments can develop and promote a deeper understanding of GHG emissions associated with their communities by reporting on both GHG emissions sources and activities. A purely source- based emissions inventory could be summed to estimate total emissions released within the community's jurisdictional boundary. In contrast, a purely activity-based emissions inventory could provide perspective on the efficiency of the community, even when the associated emissions occur outside the jurisdictional boundary. The GPC, in turn, divides community GHG emissions into Scopes 1, 2, and 3, rather than sources and activities. Figure 4 outlines these scopes and how they align emissions sources and activities.

Figure 4: 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 $MTCO_2e$.[27] 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 to 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.[28] 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.[29] Sources of emissions included agricultural soil management, enteric fermentation, manure management, urea fertilization, field burning of agricultural residues, and liming.

Table 9: 2022 Cleveland-Elyria MSA Inventory Results

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	7,503,332,440	7,554,518,825	kWh	2,775,682	3,490,047	
	Natural Gas	77,316,450	81,428,970*	MMBtu	4,108,092	4,331,927*	
	Propane	1,160,042	1,170,862	MMBtu	74,469	72,662	
	Fuel Oil	439,171	710,679	MMBtu	32,698	52,915	
	Residential Energy Total				6,990,940	7,947,551*	-12.0%
Commercial Energy	Electricity	7,061,745,524	7,820,324,931	kWh	2,577,490	4,059,675	
	Natural Gas	39,939,787	39,476,927*	MMBtu	2,124,130	2,099,640*	
	Commercial Energy Total				4,701,619	6,159,315*	-23.7%
Industrial Energy	Electricity	6,744,776,571	7,544,519,035	kWh	2,504,137	3,948,446	
	Natural Gas	10,426,661	9,567,373*	MMBtu	553,390	507,783*	
	Non-Utility Fuels				1,881,758	2,331,816	
	Industrial Energy Total				4,939,298	6,788,045*	-27.2%
Transportation & Mobile Sources	Gasoline	16,221,006,125	15,539,152,438	VMT	5,906,666	6,303,887	
	Diesel	1,171,752,406	1,167,907,440	VMT	1,963,690	2,018,767	
	Aviation				422,032	422,056	
	Rail Transportation				160,461	6,522	
	Public Transit				20,815	37,750	
	Water Transportation				207,269	249,241	
	Off-Road				76,245	106,369	
	Transportation & Mobile Sources Total				8,757,178	9,144,592	-4.2%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	2,429,767	2,450,730	Tons	1,370,110	1,422,575	
	Composting	246,735	304,938	Tons	34,042	21,233	
	Combustion of Solid Waste	1,838	890	Tons	637	308	
	Solid Waste Total				1,404,789	1,444,115	-2.7%
Water & Wastewater	Septic Systems				86,966	89,524	
	Combustion of Digester Gas				1,305	19	
	Combustion of Biosolids & Sludges				10,152	12,480	
	N2O Emissions				15,390	14,049	
	Water & Wastewater Total				113,813	116,072	-1.9%
Process & Fugitive Emissions	Natural Gas Distribution	131,437,016	169,904,636	MMBtu	232,603	319,055	
	Gas and Oil Wells				587,892	587,892	
	Other Process and Fugitive Emissions				1,027,611	1,148,564	
	Process & Fugitive Emissions Total				1,848,105	2,055,510	-10.1%
	HFCs (Refrigerants)				1,140,996	1,014,496	12.5%
	Agriculture				254,470	296,577	-14.2%
	Total Gross Emissions				30,151,210	34,966,243*	-13.8%
	Removals from Forest & Trees Emissions Total				-1,169,371		
	Total Emissions with Sequestration				28,981,839	33,796,872*	-14.2%

Table 10: 2022 Cuyahoga County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	4,041,822,934	4,220,828,789	kWh	1,491,333	1,839,880	
	Natural Gas	51,930,121	55,215,074*	MMBtu	2,761,815	2,936,698*	
	Propane	526,327	497,744	MMBtu	32,663	30,889	
	Fuel Oil	46,078	84,972	MMBtu	3,431	6,327	
	Residential Energy Total				4,289,242	4,813,793*	-10.9%
Commercial Energy	Electricity	4,770,754,859	5,224,248,774	kWh	1,757,422	2,781,715	
	Natural Gas	27,127,596	27,123,308*	MMBtu	1,445,128	1,442,594*	
	Commercial Energy Total				3,202,550	4,224,309*	-24.2%
Industrial Energy	Electricity	4,860,439,583	5,566,716,131	kWh	1,792,250	2,964,066	
	Natural Gas	5,183,373	3,489,616 *	MMBtu	275,118	185,210*	
	Non-Utility Fuels				1,779,750	2,242,573	
	Industrial Energy Total				3,847,118	5,391,849*	-28.6%
Transportation & Mobile Sources	Gasoline	8,932,129,598	8,763,716,875	VMT	3,240,546	3,534,879	
	Diesel	671,278,205	658,621,243	VMT	1,120,922	1,137,775	
	Aviation				422,031	422,044	
	Rail Transportation				72,191	6,335	
	Public Transit				18,956	37,750	
	Water Transportation				159,484	202,686	
	Off-Road				41,510	59,275	
	Transportation & Mobile Sources Total				5,075,639	5,400,744	-6.0%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	1,533,251	1,509,312	Tons	864,578	876,110	
	Composting	137,661	185,105	Tons	18,993	12,888	
	Combustion of Solid Waste	938		Tons	325		
	Solid Waste Total				883,896	888,998	-0.6%
Water & Wastewater	Septic Systems	242,078	242,078	Tons	28,571	29,412	
	Combustion of Digester Gas	86,600	83,600	Service Population	38	8	
	Combustion of Biosolids & Sludges				10,152	12,480	
	N2O Emissions				11,321	11,945	
	Water & Wastewater Total				50,082	53,845	-7.0%
Process & Fugitive Emissions	Natural Gas Distribution	88,891,205	102,309,483	MMBtu	156,040	196,978	
	Gas and Oil Wells				143,385	143,385	
	Other Process and Fugitive Emissions				830,389	918,180	
	Process & Fugitive Emissions Total				1,129,813	1,258,543	-10.2%
	HFCs (Refrigerants)				689,406	614,462	12.2%
	Agriculture				1,364	2,135	-36.1%
	Total Gross Emissions				19,169,110	22,648,678*	-15.4%
	Removals from Forest & Trees Emissions Total				-233,766		
	Total Emissions with Sequestration				18,935,344	22,414,912*	-15.5%

Table 11: 2022 Geauga County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	458,200,020	480,096,397	kWh	169,694	207,535	
	Natural Gas	2,734,405	2,747,811*	MMBtu	145,423	146,147*	
	Propane	88,171	91,272*	MMBtu	5,472	5,664	
	Fuel Oil	196,857	315,188*	MMBtu	14,657	23,468	
	Residential Energy Total				335,245	382,814*	-12.4%
Commercial Energy	Electricity	281,974,308	335,961,964	kWh	104,429	145,228	
	Natural Gas	1,232,970	1,078,0398	MMBtu	65,573	57,337*	
	Commercial Energy Total				170,002	202,565*	-16.1%
Industrial Energy	Electricity	256,001,509	244,082,189	kWh	94,810	105,511	
	Natural Gas	242,149	315,578*	MMBtu	12,852	16,749*	
	Non-Utility Fuels						
	Industrial Energy Total				107,662	122,260*	-11.9%
Transportation & Mobile Sources	Gasoline	825,101,261	783,783,448	VMT	300,834	317,712	
	Diesel	62,009,008	58,994,453	VMT	103,636	98,384	
	Aviation						
	Rail Transportation						
	Public Transit						
	Water Transportation						
	Off-Road				4,877	6,484	
	Transportation & Mobile Sources Total				409,347	422,580	-3.1%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	77,953	73,078	Tons	43,957	42,420	
	Composting	33,607	37,702	Tons	4,637	2,625	
	Combustion of Solid Waste	4		Tons	2		
	Solid Waste Total				48,595	45,045	7.9%
Water & Wastewater	Septic Systems	93,859	93,859	Service Population	11,078	11,404	
	Combustion of Digester Gas						
	Combustion of Biosolids & Sludges						
	N2O Emissions				312	30	
	Water & Wastewater Total				11,389	11,434	-0.4%
Process & Fugitive Emissions	Natural Gas Distribution	4,125,566	3,652,561	MMBtu	7,189	7,368	
	Gas and Oil Wells				134,546	134,546	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				141,735	141,914	-0.1%
	HFCs (Refrigerants)				52,368	46,345	13.0%
	Agriculture				58,335	66,863	-12.8%
	Total Gross Emissions				1,334,679	1,441,821*	-7.4%
	Removals from Forest & Trees Emissions Total				-361,018		
	Total Emissions with Sequestration				973,661	1,080,803*	-9.9%

Figure 5: 2022 Cuyahoga County GHG Emissions by Sector

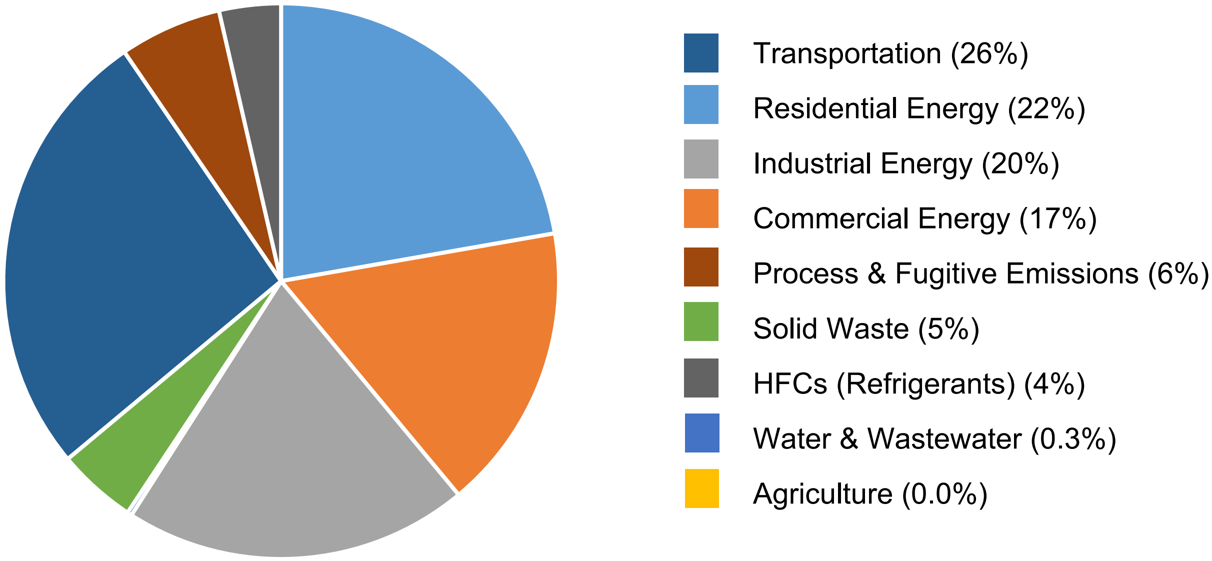


Figure 6: 2022 Geauga County GHG Emissions by Sector

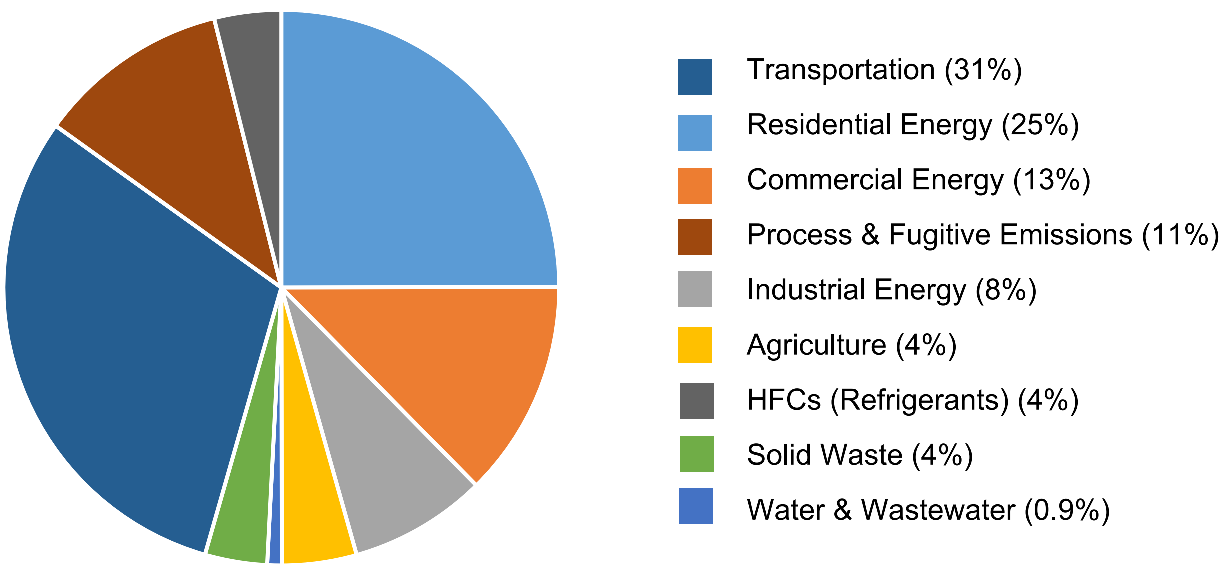


Table 12: 2022 Lake County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	883,041,980	906,150,299	kWh	334,437	506,729	
	Natural Gas	7,930,031	8,351,461*	MMBtu	421,745	444,185*	
	Propane	94,451	85,581	MMBtu	5,862	5,311	
	Fuel Oil	67,813	102,668	MMBtu	5,049	7,644	
	Residential Energy Total				767,092	963,869*	-20.4%
Commercial Energy	Electricity	839,859,052	967,757,939	kWh	318,282	539,165	
	Natural Gas	3,722,638	3,371,014*	MMBtu	197,982	179,292*	
	Commercial Energy Total				516,264	718,457*	-28.1%
Industrial Energy	Electricity	548,761,691	577,753,228	kWh	206,946	319,314	
	Natural Gas	1,248,587	559,026*	MMBtu	66,268	29,670*	
	Non-Utility Fuels				96,603	84,850	
	Industrial Energy Total				369,817	433,834*	-14.8%
Transportation & Mobile Sources	Gasoline	2,327,756,398	1,775,729,312	VMT	853,752	727,972	
	Diesel	147,938,364	133,451,715	VMT	215,316	231,624	
	Aviation					6	
	Rail Transportation				28,438		
	Public Transit				1,859		
	Water Transportation				30,342	33,795	
	Off-Road				9,796	14,002	
	Transportation & Mobile Sources Total				1,139,549	1,007,399	13.1%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	275,550	238,705	Tons	155,378	138,561	
	Composting	30,297	38,372	Tons	4,180	2,672	
	Combustion of Solid Waste			Tons			
	Solid Waste Total				159,559	141,233	13.0%
Water & Wastewater	Septic Systems	119,913	119,913	Service Population	14,153	14.569	
	Combustion of Digester Gas	149,642	55,567	Service Population	9	3	
	Combustion of Biosolids & Sludges						
	N2O Emissions				1,187	826	
	Water & Wastewater Total				15,349	15.398	-0.3%
Process & Fugitive Emissions	Natural Gas Distribution	12,884,994	11,734,203	MMBtu	22,415	23,671	
	Gas and Oil Wells				65.436	65,436	
	Other Process and Fugitive Emissions				197.222	230,384	
	Process & Fugitive Emissions Total				285,074	319,491	-10.8%
	HFCs (Refrigerants)				127,409	113,001	12.8%
	Agriculture				12,112	12,545	-3.5%
	Total Gross Emissions				3,392,180	3,725,227*	-8.9%
	Removals from Forest & Trees Emissions Total				-165,452		
	Total Emissions with Sequestration				3,226,728	3,559,775*	-9.4%

Table 13: 2022 Lorain County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	1,307,302,496	1.173.965.126	kWh	475,290	566.728	
	Natural Gas	9,361,754	9.562.577*	MMBtu	494,039	508.601*	
	Propane	251,200	275.145	MMBtu	15,589	17.075	
	Fuel Oil	46,823	74.104	MMBtu	3,486	5.518	
	Residential Energy Total				988,404	1.097.923*	-10.0%
Commercial Energy	Electricity	764,282,012	855.797.279	kWh	253.280	391.673	
	Natural Gas	4,954,905	4.892.982*	MMBtu	263.518	260.241*	
	Commercial Energy Total				516.799	651.914*	-20.7%
Industrial Energy	Electricity	646,218,556	704,467,502	kWh	525.078	313.334	
	Natural Gas	2,474,828	3,536,054*	MMBtu	131.350	187.674*	
	Non-Utility Fuels				5.405	4.393	
	Industrial Energy Total				388.833	505.401*	-23.1%
Transportation & Mobile Sources	Gasoline	2,327,756,398	2,367,586,799	VMT	857,294	973.673	
	Diesel	174,938,364	177,931,690	VMT	295,379	309.532	
	Aviation				1	6	
	Rail Transportation				50,351	187	
	Public Transit						
	Water Transportation				17.443	12,760	
	Off-Road				12,854	17,242	
	Transportation & Mobile Sources Total				1,233,321	1,313,400	-6.1%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	337,393	406,699	Tons	190,251	237,818	
	Composting	41,085	33,902	Tons	5,669	2,361	
	Combustion of Solid Waste	890	890	Tons	309	308	
	Solid Waste Total				196,228	240,487	-18.4%
Water & Wastewater	Septic Systems	171,461	171,461	Service Population	20,237	20,832	
	Combustion of Digester Gas	118,000	113,844	Service Population	90	7	
	Combustion of Biosolids & Sludges						
	N2O Emissions				2,160	1,141	
	Water & Wastewater Total				22,488	21,980	2.3%
Process & Fugitive Emissions	Natural Gas Distribution	16,279,432	35,634,279	MMBtu	30,059	61,824	
	Gas and Oil Wells				62,566	62,566	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				92,625	124,390	-25.5%
	HFCs (Refrigerants)				171,773	152,041	13.0%
	Agriculture				94,931	120,144	-21.0%
	Total Gross Emissions				3,705,403	4,227,680*	-12.4%
	Removals from Forest & Trees Emissions Total				-206,873		
	Total Emissions with Sequestration				3,498,530	4,020,807*	-13.0%

Figure 77: 2022 Lake County GHG Emissions by Sector

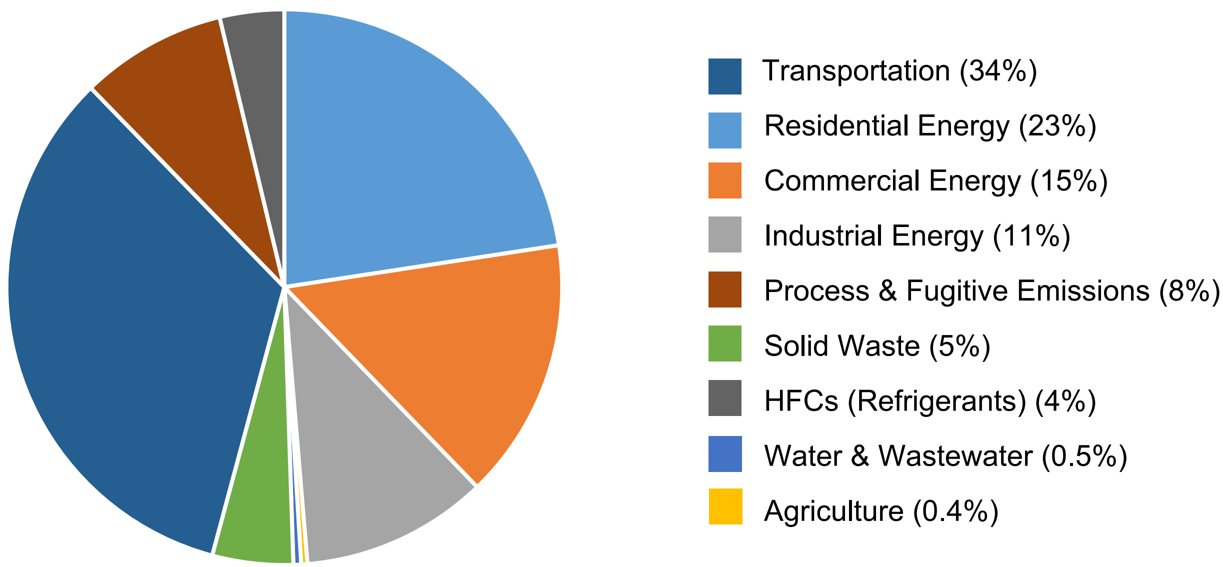


Figure 8: 2022 Lorain County GHG Emissions by Sector

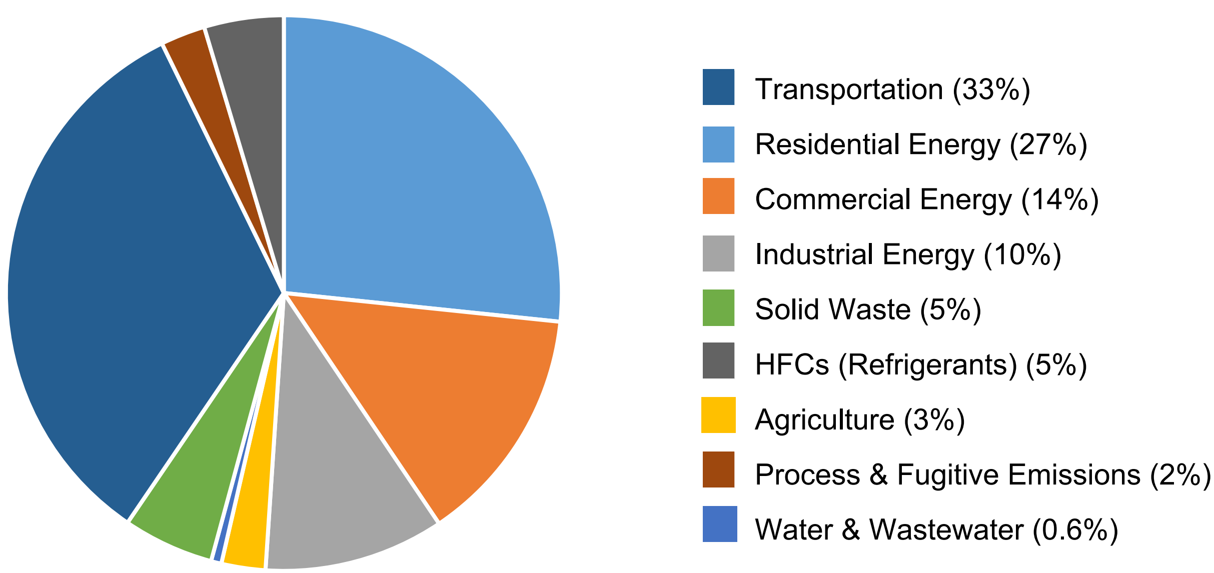
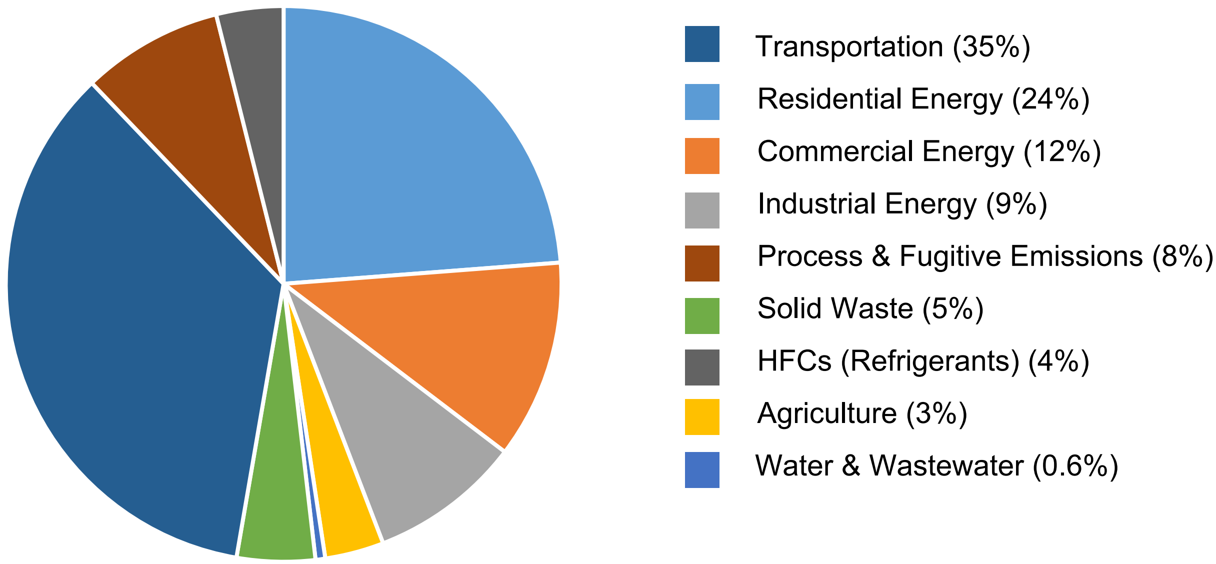


Table 14: 2022 Medina County Emissions Inventory

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Residential Energy	Electricity	812,965,010	773,478,214	kWh	304,929	369.176	
	Natural Gas	5,360,139	5,552,047*	MMBtu	285,070	296.296*	
	Propane	199,892	221,121	MMBtu	14,883	13.723	
	Fuel Oil	81,559	133,746	MMBtu	6,075	9.958	
	Residential Energy Total				610,957	689.152*	-11.3%
Commercial Energy	Electricity	404,875,293	436,558,974	kWh	144,077	201,894	
	Natural Gas	2,856,678	3,011,584*	MMBtu	151,928	160,176*	
	Commercial Energy Total				296,004	362,070*	-18.2%
Industrial Energy	Electricity	423,355,232	451,505,985	kWh	158,054	246,221	
	Natural Gas	1,277,725	1,667,099*	MMBtu	67,815	88,480*	
	Non-Utility Fuels						
	Industrial Energy Total				225,869	334,701*	-32.5%
Transportation & Mobile Sources	Gasoline	1,808,330,158	1,848,336,004	VMT	654,240	749,651	
	Diesel	135,901,815	138,908,339	VMT	228,436	241,452	
	Aviation						
	Rail Transportation				9,436		
	Public Transit						
	Water Transportation						
	Off-Road				7,208	9,366	
	Transportation & Mobile Sources Total				899,321	1,000,469	-10.1%

Sector	Fuel or Source	Usage		Unit	Emissions (MTCO2e)		Percent Change
		2022	2018		2022	2018	
Solid Waste	Waste Generation	205,620	219,936	Tons	115,946	127,666	
	Composting	9,857	9,857	Tons	564	686	
	Combustion of Solid Waste	6		Tons	2		
	Solid Waste Total				116,512	128,352	-9.2%
Water & Wastewater	Septic Systems	109,535	109,535	Service Population	12,928	13,308	
	Combustion of Digester Gas	82,600	25,000	Service Population	1,168		
	Combustion of Biosolids & Sludges						
	N2O Emissions				409	107	
	Water & Wastewater Total				14,505	13,415	8.1%
Process & Fugitive Emissions	Natural Gas Distribution	9,255,819	16,574,163	MMBtu	16,900	29,214	
	Gas and Oil Wells				181,958	181,958	
	Other Process and Fugitive Emissions						
	Process & Fugitive Emissions Total				198,858	211,172	-5.8%
	HFCs (Refrigerants)				100,039	88,646	12.9%
	Agriculture				87,728	94,890	-7.5%
	Total Gross Emissions				2,549,792	2,922,867	-12.8%
	Removals from Forest & Trees Emissions Total				-202,262		
	Total Emissions with Sequestration				2,347,530	2,720,605	-13.7%

Figure 9: 2022 Medina County Emissions by Sector

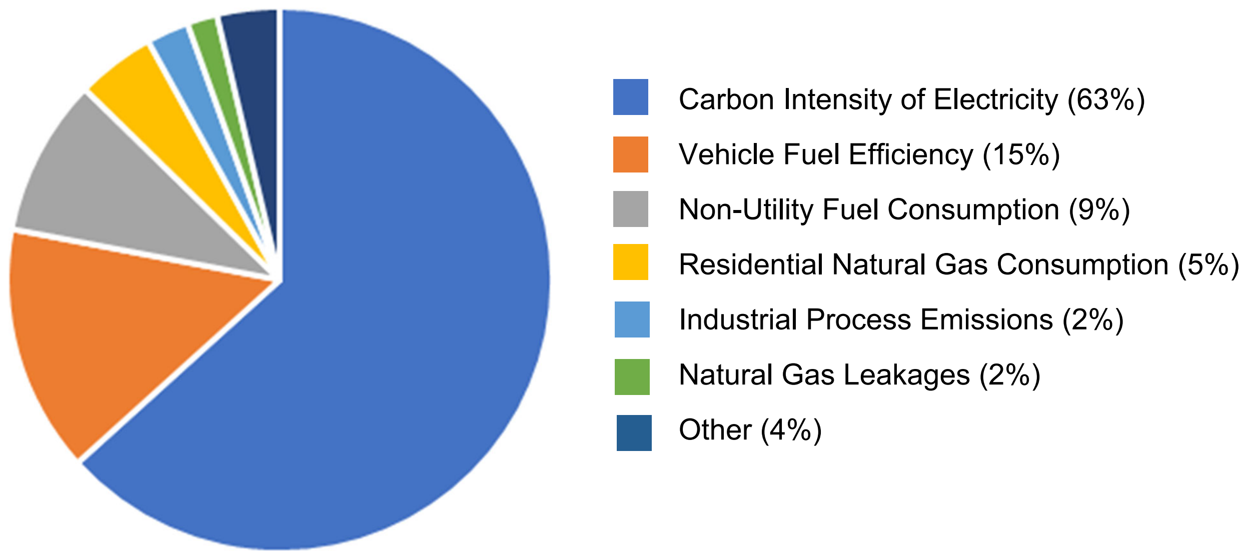


2.8. Cleveland-Elyria MSA GHG Emissions Trends: 2018 to 2022

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 metric tons of carbon dioxide equivalent ($MTCO_2e$) 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 10 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 in order 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.

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.”[30] 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 near-term targets across the MSA, though nearly all of these communities have committed to achieving net zero emissions by 2050. The targets that the NOACA Board adopted for this CCAP fall squarely within this range and aligns with the targets the region previously identified in its PCAP.

3.2. Reflecting Climate Change Science

As the science has become clearer and the likely impacts of climate change get 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."[31] Adopting an SBT 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 an SBT for the region.

3.3. Matching Emissions Reduction Trends

The 2030 targets that the U.S. adopted are based on 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.[32] 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.[33]

Cleveland used two main approaches. First, it calculated the share of Ohio GHG emissions that the MSA accounted for it 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 2005 before applying these ratios to statewide per capita emissions 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 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 this decision further, the City of Cleveland analyzed the potential public health benefits of achieving 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.[34] Staff analyzed five potential reduction targets, outlined in Table 15, along with 100% reduction (representing net zero emissions).[35]

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

Option	Projected 2030 Emissions ($MMtCO_2e$)	Annual Rate of Reduction	2005 Emissions ($MMtCO_2e$)	2018 Emissions ($MMtCO_2e$)	Percent Reduction from 2005 Emissions	Percent Reduction from 2018 Emissions
Option 1	22.78	3.4%	40.53 - 46.83	34.97	43.8-51.4%	34.8%
Option 2	17.04	6.9%			58.0-63.6%	51.3%
Option 3	**17.84**	**6.4%**			**56.0-61.9%**	**49.0%**
Option 4	19.32-19.84	5.1-5.4%			51.1-57.6%	43.3-44.7%
Option 5	12.84	10.1%			68.3-72.6%	63.3%

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.

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 long 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.[36] 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).[37] 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 for the first time during 2024.[38] 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. Taking immediate action to reduce GHG emissions is essential for limiting the impacts of climate change, as "every increment of global warming will intensify multiple and concurrent hazards."[39] 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.[40]

4.1. Observed Impacts of Climate Change on the 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 as a whole.[41] 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 on the basis of current policies for addressing climate change, then Northeast Ohio could warm by about 5.4°C (9.8°F).[42]

Because average temperatures are just that, they can conceal significant fluctuations and changes in extremes. Figure 11, 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 was 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.[43]

This demonstrates the fundamental shift if 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 12.[44] 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 10: Distribution of Annual Mean Temperatures in Low Warming Scenario

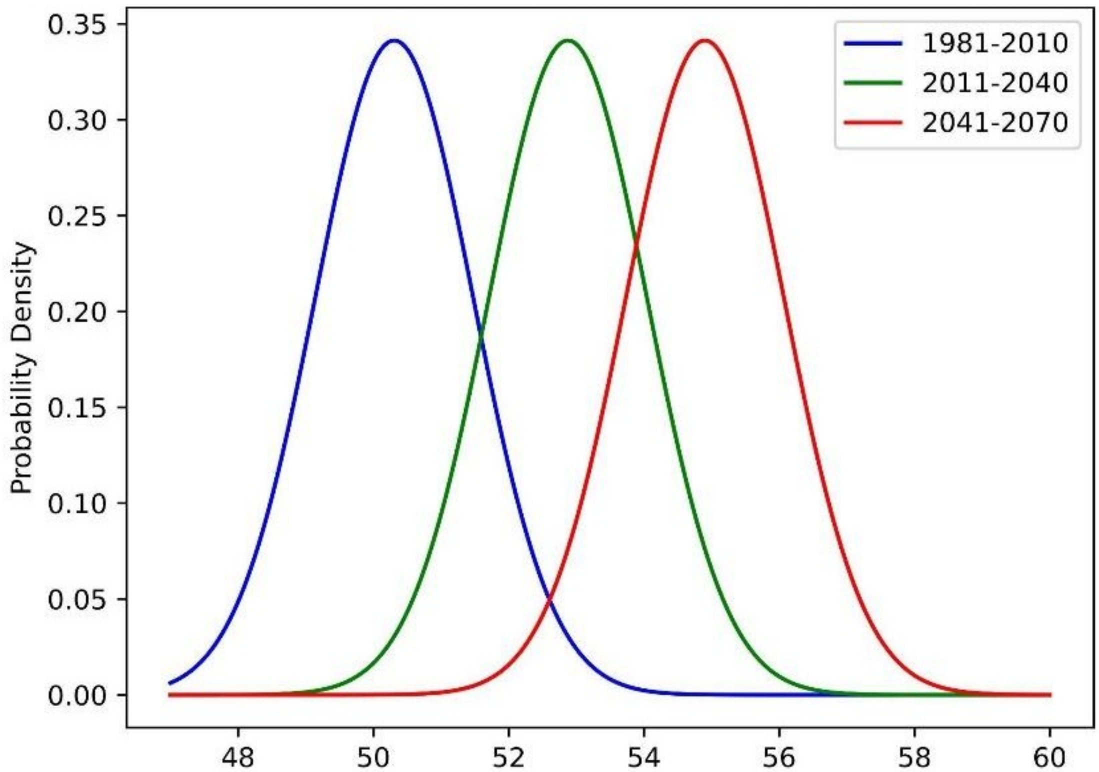
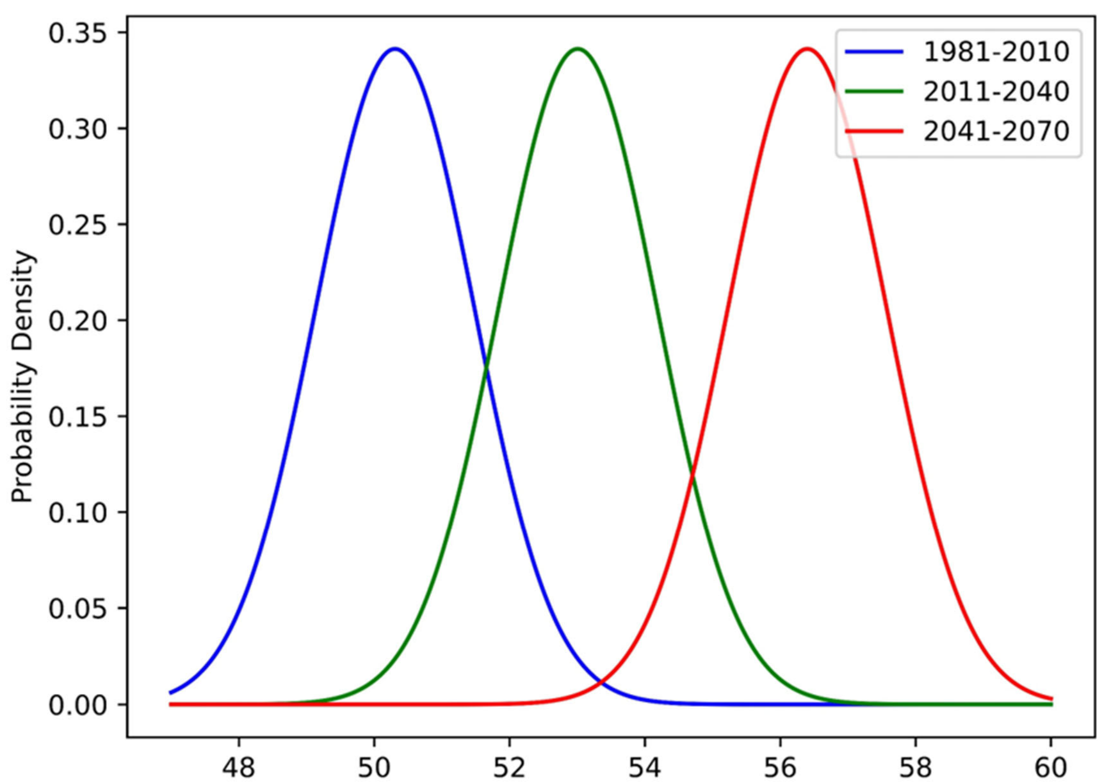


Figure 1212: Distribution of Annual Mean Temperatures in High Warming Scenario



These changes have wide ranging implications, ranging 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, leading 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 than 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.[45]

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

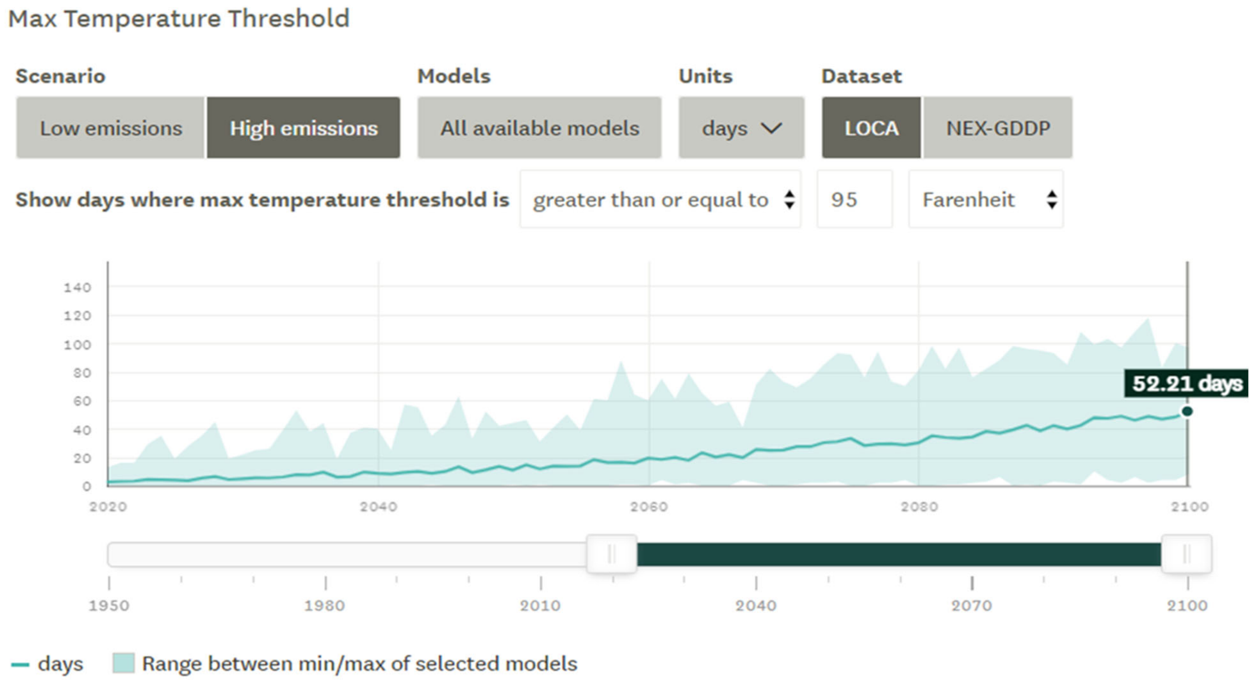
During 2022 and 2023, NOACA developed a CRVA for the MSA. NOACA partnered with ICLEI USA to review available resources and localized climate projections to learn which hazards are most likely to affect the five counties, as well as to evaluate the seriousness of their impacts. Based upon this literature and extensive engagement with stakeholders, NOACA selected extreme heat, heavy rainfall and flooding, and severe convective storms as primary hazards of focus to assess regional vulnerability. The City of Cleveland conducted its own CRVA in 2023 and 2024, which complements the NOACA assessment.[46] Both reviews included extensive stakeholder and public engagement processes, as discussed in Chapter 1. Table 16 identifies the priority climate hazards identified through each process.

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. While from 1961 to 1990, the region experienced less than one day per year where temperatures exceeded 95°F, on average, by comparison, it is projected that by the end of the century, it may reach 95°F in the Cleveland-Elyria MSA as many as 52 days each year.[47] 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, days when the temperature low is 75°F or higher, which deny people and wildlife the opportunity to cool off from daytime temperatures, are particularly dangerous to health and well-being and by 2100 there are likely to be 30 on average warm nights annually.[48]

Figure 13: Projection for Number of 95°F Days per Year for Cleveland-Elyria MSA



In areas where there is a high concentration of older housing stock, for example, First Rung suburbs such as East Cleveland, where there is a high concentration of LIDAC census tracts, the majority of the housing stock was not constructed to address the climate-imposed heating and cooling needs that our region will soon face. As low income populations tend to reside in older housing stock which is less energy efficient, 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.[49] 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%, placing an additional strain on the region's stormwater infrastructure and increasing the risk of flash flood events.[50] 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 day per decade in Lorain County, while the largest increase was 1.42 days per decade in Cuyahoga County.[51]

Projecting future changes in flood risk is complex 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.[52] 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.[53] 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 2014-2023, 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.[54] Most recently, a cluster of tornadoes touched down on August 6, 2024, causing severe damage and leaving hundreds of thousands of residents without power for days.[55]

Research suggests these types of storms will become more frequent and intense due to a changing climate.[56] 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.[57]

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 $PM_{2.5}$.[58] 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.[59]

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.[60] However, this reduction is not guaranteed; under higher warming scenarios, $PM_{2.5}$ levels actually increase in Northeast Ohio.[61] 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.

Figure 14: Canadian Wildfire Smoke in Cleveland-Elyria MSA, June 2023

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

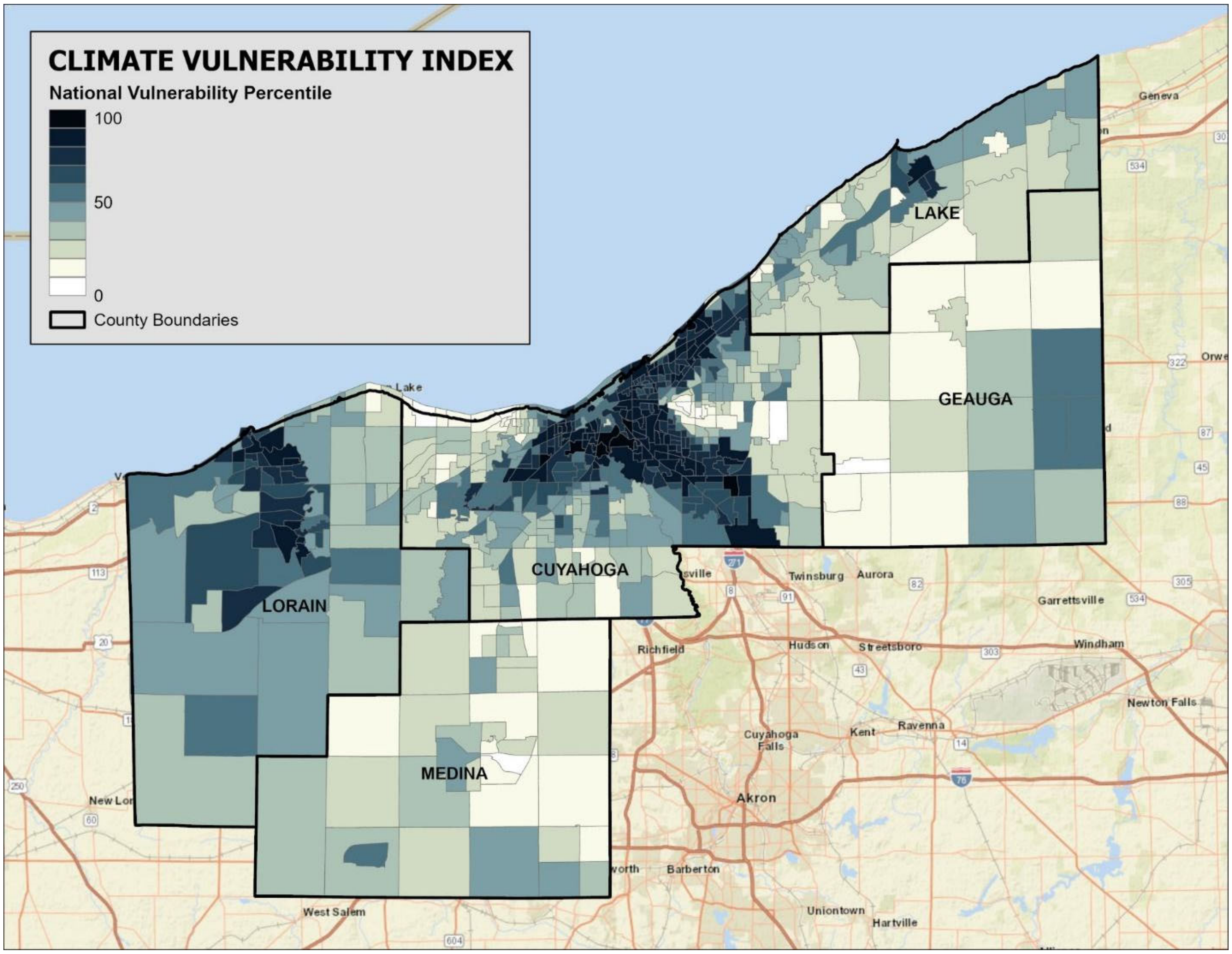
June 30th 2023 at 9:42am - 47 AQI

4.3. Vulnerable Population Groups

Climate vulnerability refers to one's "propensity or predisposition…to be affected adversely by hazards."[62] 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.[63] Both social and place-based factors affect this underlying susceptibility. Social vulnerability, largely the result of social inequalities, encompasses "those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond" and place inequalities are those that are tied to specific geographic areas, including "characteristics of communities and the built environment, such as the level of urbanization, growth rates, and economic vitality."[64] While climate vulnerable population groups are spread across the MSA, they are largely concentrated in Cuyahoga County, particularly within the City of Cleveland.

Figure 15 displays the national percentile rank for each Census tract according to the Climate Vulnerability Index (CVI).[65] 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 15: Climate Vulnerability Index Scores by Census Tract

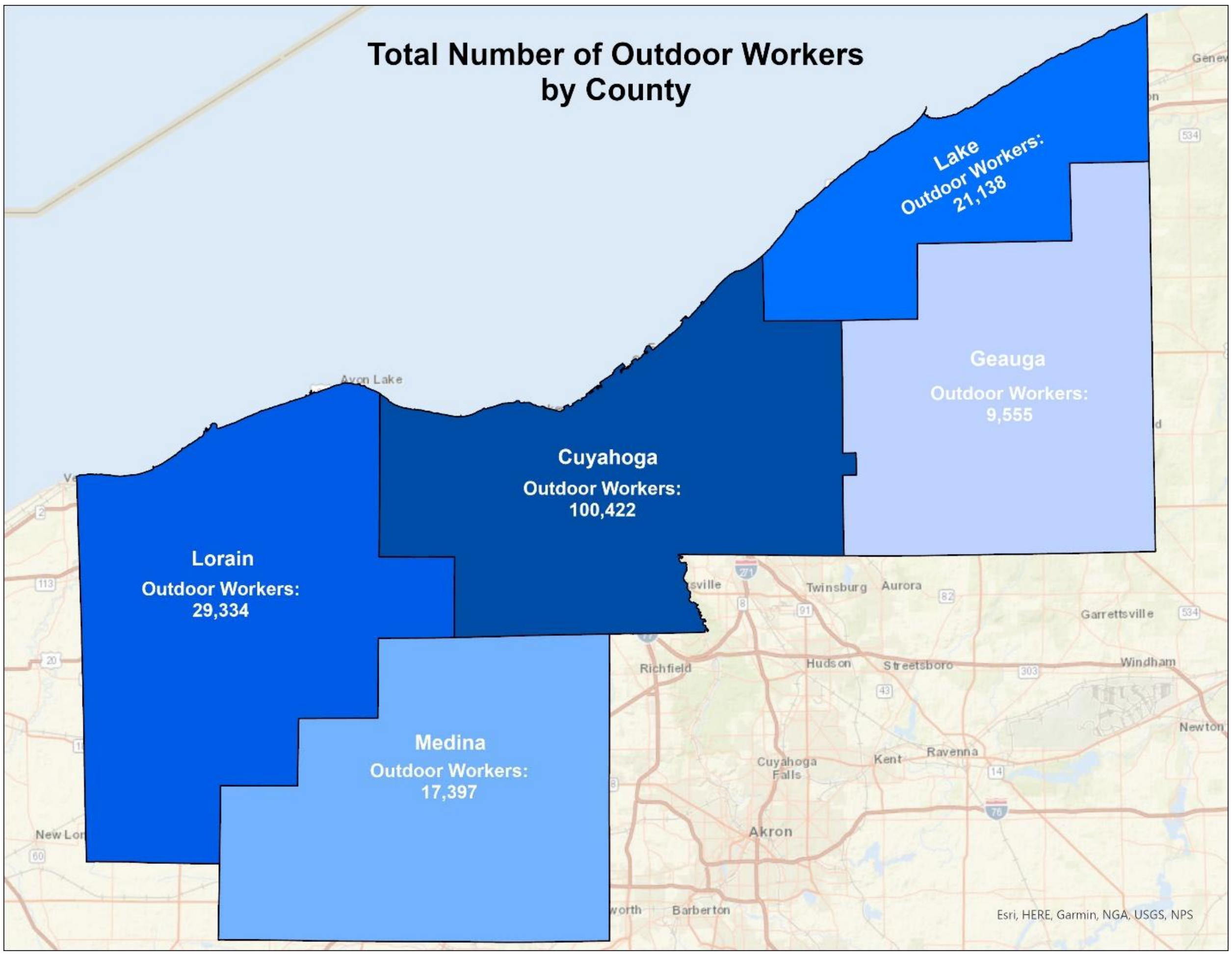


As the City of Cleveland's CRVA shows, outdoor workers are among the most climate vulnerable groups in the MSA. Given the nature of their work, they are particularly vulnerable to increased temperatures, which expose them to financial and physical harms. Outdoor workers are fairly evenly distributed, though there are slightly higher concentrations in Lorain and Geauga Counties, as shown in Table 18.[66] Figure 16 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.

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 16: 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. 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 [67]

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%

5. Costs of Climate Inaction for Cleveland-Elyria MSA

While decarbonization carries real financial and social costs, so does inaction. Choosing not to act on climate change poses significant, tangible risks to the region. By taking collective action to decarbonize our economy, leaders can engage and educate residents, businesses, and organizations on the threat of climate change and the actions needed to face that crisis. If the MSA fails to act, it will leave community members vulnerable not only to the changing climate, but also to losing out on the 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. By 2080, the climate that has defined this region for centuries will be gone. In its place, the region will adopt a warmer and more humid climate that more closely resembles central Arkansas.[68] 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).[69] In a Business as Usual future, in the 2040s the hardiness zones throughout the MSA are expected to be 7a and 7b.[70] For grape growers, orchardists, and dairy 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, as Lake Erie has buffered the extreme heat that can affect other parts of the Midwest. Climate change will increase the burden of 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.[71]

Lost Opportunities: If regional leaders fail to act decisively, other regions may seize upon some of the opportunities identified in this CCAP. Two key examples particularly relevant. First, given the current demand for clean, firm power for data centers, private vendors may contract directly with Perry Nuclear Power Plant to expand its generation capacity. If this occurs, the region would face a less straightforward path to meeting emissions reduction goals. Second, other Great Lakes cities have evaluated investing in offshore wind, including Chicago and Buffalo.[72] 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 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.

Missed Job Opportunities: 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.[73] In order to meet the opportunities in transitioning our buildings, transportation and electricity infrastructure across the MSA, this report demonstrates enormous needs for skilled labor and new businesses. Inaction will lead to these opportunities not materializing in the MSA; as other regions accelerate their transition, these opportunities and jobs will gravitate to those regions, making it hard for the region 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), which is a tool to translate the effects of climate change into economic terms in order to help decision makers better understand the economic impacts of decisions that affect climate pollution.[74] To estimate the social cost of climate inaction, the City of Cleveland and the CRDF team projected cumulative GHG emissions within the MSA from 2023-2050 under the Business As Usual (BAU) scenario, which is outlined in the next chapter.

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 for translating this emissions estimate into estimated costs.[75] Using this approach, which recommends 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 entire GDP during 2023.[76] Annualized costs total more than $6 billion, with a range of approximately $4.2-10.1 billion, depending on the discount rate.[77] 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	Estimated Annual Cost (2030)	Estimated Annual Cost (2040)	Estimated Annual Cost (2050)	Estimate Cumulative Costs (2023-2050)
Cuyahoga	$4.1 billion	$3.7 billion	$3.3 billion	$108.1 billion
Geauga	$287 million	$259 million	$233 million	$7.5 billion
Lake	$730 million	$659 million	$592 million	$19.1 billion
Lorain	$797 million	$720 million	$647 million	$20.9 billion
Medina	$548 million	$495 million	$445 million	$14.4 billion
Total MSA	$6.5 billion	$5.9 billion	$5.3 billion	$170 billion

These numbers demonstrate, when considering the direct costs of climate adaptation and infrastructure resilience, the financial imperative for decisive action become even clearer.

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, but this section updates that analysis using the 2022 GHG inventory as the baseline. The following assumptions from the PCAP BAU scenario remain:

- **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 and 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.[78] 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[79] (changes in passenger cars, light truck, medium, and heavy-duty truck[80] 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).[81] 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.[82] 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 are outlined, below, in Figure 17 and Table 21. If the Cleveland-Elyria MSA takes no additional action, net GHGs will reach 27.91 and 25.15 $MMTCO_2e$ in 2030 and 2050, respectively. These values represent reductions of 17.4% (2030) and 25.6% (2050) from 2018 levels.

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

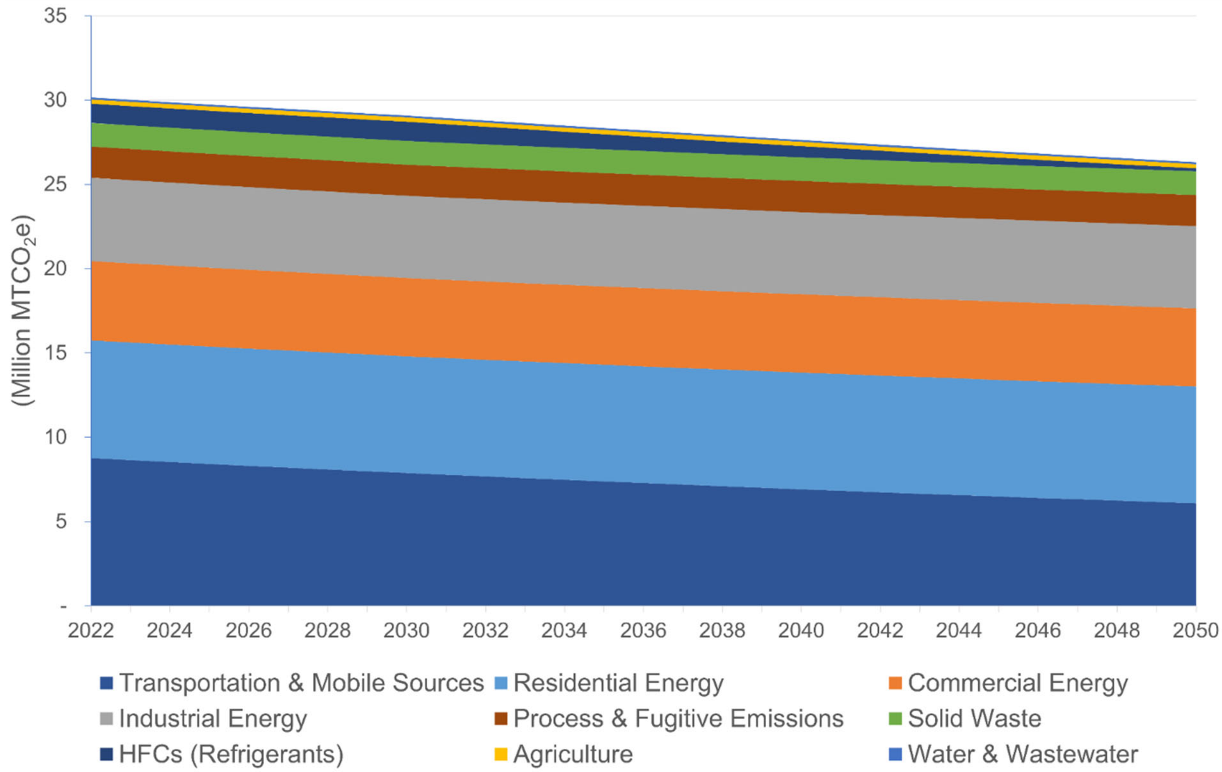


Table 21: BAU Scenario GHG Emissions for Cleveland-Elyria MSA, 2030-2050

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**

7. GHG Emissions Reduction Measures

7.1. Summary of Emissions Reduction Measures

As Figure 18, below, 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. 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. In order to meet its target, the MSA will need to secure additional external support to accelerate implementation of these measures.

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

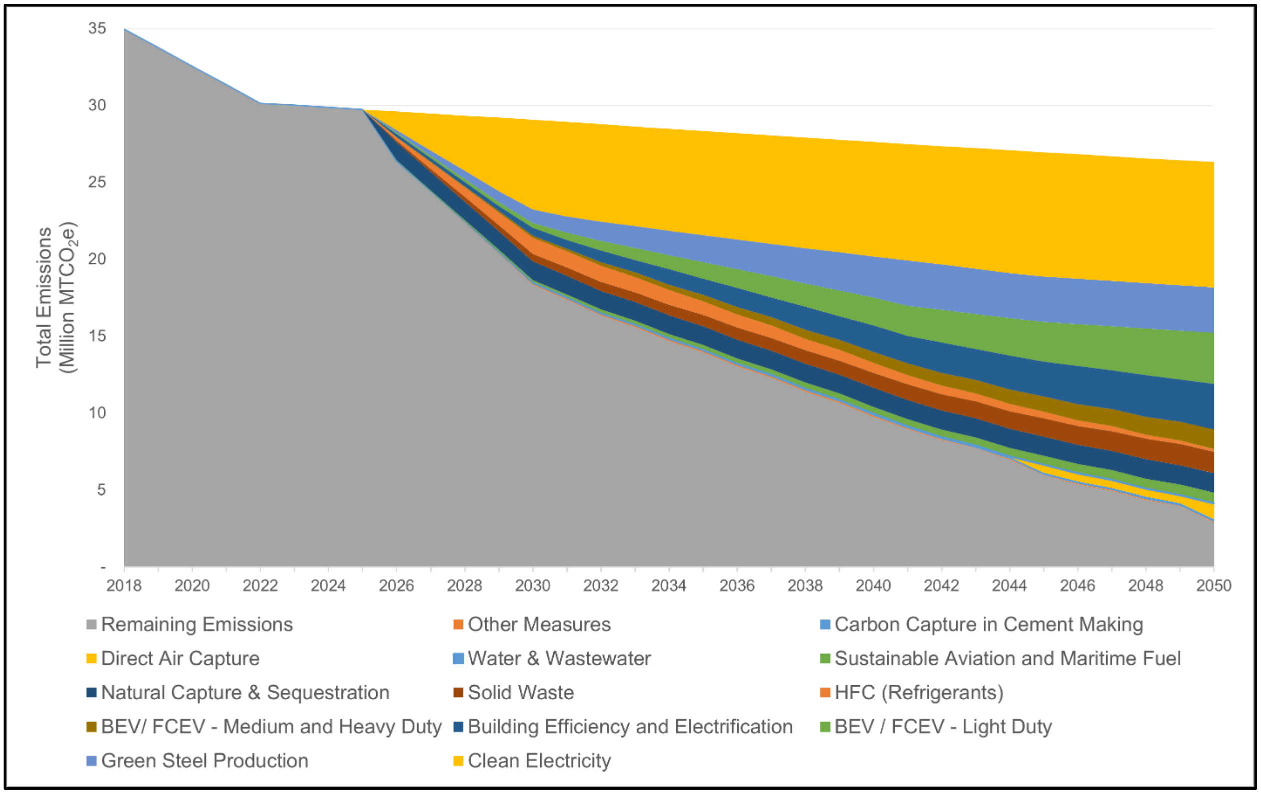


Table 22, below, breaks down the GHG reductions associated with each measure. It also identifies which PCAP priority measure each CCAP measure corresponds to. In a few instances, CCAP measures have no direct PCAP equivalent, which reflects the fact that CCAPs must include a full suite of measures that will enable the MSA to reduce emissions from all significant sources. The CCAP also adds additional measures, including those that will have long-term implementation timelines (e.g. 2040-2050). Across all measures, the largest savings come from clean electricity, which accounts for 54.4% of total emissions reductions in 2030 and 34.7% in 2050.

Table 23 provides a more complete overview of the CCAP measures, including which community types they are most applicable for, 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 from extreme weather. Low-regret strategies have immediate benefits, can be implemented in the near term, and represent the best solutions for the moment.

As the rest of this chapter highlights, the cornerstone of this strategy is electrification, which remains 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 in enabling a transition from fossil fuel-based energy sources to cleaner options. The accelerated deployment of clean energy technologies, such as advanced grid infrastructure, geothermal, wind, and nuclear, will facilitate the replacement of natural gas and other 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. While the incremental deployment of clean energy sources may not directly alter the comparative emissions profile vis-à-vis the BAU scenario, given that much of the additional supply is absorbed by new electrified end uses, its strategic importance cannot be overstated.

Despite the depth and breadth of this decarbonization strategy, certain sectors remain difficult to fully decarbonize by 2050. Notably, there remain 2.87 $MMTCO_2e$ 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.

Recognizing these barriers, this CCAP advances an integrated suite of strategies that sequester carbon, which is a necessary complement to direct mitigation efforts. The CCAP expands the nature-based solutions measures from the PCAP—such as habitat restoration and reforestation—and adds additional technological approaches, including direct air capture (DAC) and geologic sequestration, to offset emissions from hard-to-abate sectors. Emissions removals, both from nature-based solutions and DAC, 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 2050 targets on time.

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

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

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: Overview of Emissions Reduction Measures

CCAP Measure	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Community enrollment in renewable energy CCA	All	$	Short-Term	Low-Regret	Yes	N/A
Opt-in Public Pricing Program for 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
Intelligent grid management systems	All	$$	Short- to Long-Term		Yes	No
Grid-scale power systems modernization	All	$$$	Short- to Long-Term		Yes	No
Community-serving microgrid and minigrid systems.	All	$$	Short-Term, Medium-Term		Yes	Yes
Convert lighting to LEDs	All	$	Short- to Long-Term	Low-Regret	Yes	Yes
Utility-scaled solar	All	$$	Short- to Long-Term		Yes	Yes
Offshore wind	Legacy City	$$$	Long-Term		Unclear - project approved, but in limbo	No
Brownfields to Brightfields	Legacy City, Established City & Town, Rural Community	$$	Short-Term, Medium-Term		Yes	Yes
Residential rooftop solar	All	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Commercial-scale rooftop & parking lot solar	All	$$	Short- to Long-Term	Low-Regret	Yes	Yes
District thermal energy systems	All	$$$	Short- to Long-Term		Yes	No
District or utility-scale battery storage - Long duration (>10 hrs)	Legacy City	$$	Long-Term		Yes	Yes
Hydrogen as an energy carrier	Legacy City, Established City & Town, First Ring Suburb	$$$	Medium- to Long-Term		Yes, but capacity does not currently exist in MSA	Yes
New Nuclear at Perry	Outer Ring Suburb	$$$$	Long-Term		Not Currently	No

CCAP Measure	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Geothermal electricity generation	Legacy City, Rural Community	$$$	Long-Term		Yes	No
District or utility-scale battery storage - short duration (<4 hours)	Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$	Short- to Long-Term		Yes	No
Increasing Retrofit Envelope Efficiency (Deep retrofit)	Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$$	Short-Term	Low-Regret	Yes	Yes
Building System Electrification (Deep Retrofit)	Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$$	Medium- to Long-Term	Low-Regret	Yes	Yes
Incentive programs	Legacy City, Established City & Town, First Ring Suburb, Second Ring Suburb	$$	Short- to Long-Term		Yes for municipal utilities	Yes
Implementation of the latest state adopted building standards and codes	All	$$	Short- to Long-Term	No-Regret	Yes	Yes
Smart Energy Management Systems (Commercial Buildings)	All	$$$	Short- to Long-Term	Low-Regret	Yes	Yes
Material Substitution	All	$$$$	Short- to Long-Term		Yes	Yes
Modular and Prefabricated Construction	All	$$$$	Medium- to Long-Term		Yes	Yes
Automated Building Systems and Smart Devices	All	$	Medium- to Long-Term	No-Regret	Yes for municipal utilities	Yes
Active Energy Adjustment for Grid Support (Demand Response)	All	$$$	Medium- to Long-Term		Yes for municipal utilities	Yes
Energy audits	All	$	Short-Term	No-Regret	Yes for property owners municipal utilities	No
Waste heat recovery and utilization systems	All	$$$	Short-Term to Medium-Term		Yes	No
Monitoring Systems	All	$	Short-Term	Low-Regret	Yes	No

CCAP Measure	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Energy Efficient Equipment	All	$$	Short-Term	Low-Regret	Yes	No
Automation	All	$	Short-Term		Yes	No
Reduce industrial waste	All	$$$	Short- to Long-Term	No-Regret	Yes	No
Use lower GWP gases for anesthetics	All	$	Short-Term		Yes	No
Install leak detection equipment	All	$	Short-Term	No-Regret	Yes	No
Electrification of industrial process heat	All	$$$	Medium- to Long-Term	Low-Regret	Yes	No
Green Steel at Cleveland Works	Legacy City	$$$$	Medium-Term		Yes, but technology still being developed	No
Electrify machine drives in synergy with grid decarbonization	All	$$$	Medium- to Long-Term		Yes	No
Carbon capture at Cleveland Works	Legacy City, First Ring Suburb, Outer Ring Suburb	$$$$	Medium-Term		Not Currently - would require legislative/regulatory approval	No
Post combustion carbon capture (cement making)	Legacy City, Established City & Town	$$$	Short-Term		Not Currently - would require legislative/regulatory approval	No
Invest in a regional direct air capture facility for hard to abate sectors	All	$$$$	Long-Term		Not Currently - would require legislative/regulatory approval	No
Switch industrial processes to hydrogen (steel, cement, chemical manufacturing)	Legacy City, Established City & Town	$$$$	Short- to Long-Term		Yes, but contingent on availability of H2	Yes
Expand BEV charging infrastructure	All	$$	Short-Term to Medium-Term		Yes	Yes
BEV/FCEV adoption in government fleets	All	$$	Short- to Long-Term	Low-Regret	Yes	No
BEV adoption of light-duty passenger vehicles by households	All	$$	Medium- to Long-Term	Low-Regret	Yes	Yes
Reducing Fuel Cost Access to Electric Vehicle Infrastructure	All	$$	Short-Term		Yes	Yes

CCAP Measure	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Expand BEV charging infrastructure	All	$$	Short-Term to Medium-Term		Yes	No
Expand FCEV fueling infrastructure	All	$$$	Medium- to Long-Term		Yes	No
Advance the use of sustainable liquid and gaseous fuels at regional maritime ports	Legacy City, Established City & Town	$$$$	Medium- to Long-Term	Low-Regret	Yes	Yes
Advance the use of sustainable aviation fuel at regional airports	Legacy City, First Ring Suburb, Established City & Town	$$$$	Short- to Long-Term	Low-Regret	Yes, but airlines must agree to purchase SAF	No
Intercity Passenger Rail and Coordinated Transportation Planning	All	$$$$	Medium-Term		Not Currently - would require approval from State of Ohio	Yes
Expand networks of protected bike lanes, off-street trails, and lane conversions	All	$	Short-Term	No-Regret	Yes	Yes
Increase density and mix of uses around transit stations	Legacy City, First Ring Suburb, Established City & Town	$$	Short- to Long-Term	Low-Regret	Yes	Yes
install gas capture systems for landfill methane	All	$$	Short-Term	No-Regret	Yes	No
Restaurant and grocery food waste reduction/composting program	All	$$	Short-Term	Low-Regret	Yes	Yes
Add compost bins to public facilities, parks, and sports stadiums to divert organic waste from land fills	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
Post incineration scrubbers installed at wastewater treatment facilities with fluidized bed incinerators	All	$$$	Short-Term	Low-Regret	Yes	No
Invest in high-tech equipment to help detect water leaks in municipal water infrastructure - saving water and energy once repaired	All	$	Short-Term to Medium-Term	Low-Regret	Yes	No

CCAP Measure	Community Type	Cost	Time Frame	No/Low-Regret	Authority to Implement	Funding Secured
Use climate friendly refrigerants	All	$$	Medium-Term	Low-Regret	Yes	No
End of equipment life facilities, dropoff/collection programs for refrigerants	All	$$	Short-Term	Low-Regret	Yes	Yes
Support habitat restoration and conservation	Outer Ring Suburb, Rural Community	$	Medium-Term	Low-Regret	Yes	Yes
Expand Wetland Restoration Programs	Rural Community	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Reforest agriculture lands no longer in use, increasing the regional tree canopy	Rural Community	$	Short- to Long-Term		Yes	No
Tree carbon-capture	Established City & Town, First Ring Suburb	$$	Short- to Long-Term	Low-Regret	Yes	Yes
Model mature tree protection ordinance	All	$	Short- to Long-Term	No-Regret	Yes	Yes
Expand agriculture practices to restore soil health and increase carbon sequestration	Rural Community	$	Short- to Long-Term	Low-Regret	Yes	No
Digital twin to track tree canopy	Legacy City	$$	Short- to Long-Term		Yes	No
Land bank set-asides for carbon storage	Legacy City, Rural Community	$	Short-Term	Low-Regret	Yes	No
Support community greenspace programs for small scale community-based native urban gardens, greenspaces, tree planting	All	$	Short-Term	Low-Regret	Yes	Yes

7.2. Electricity Sector

7.2.1. MSA Context

No other sector possesses as much possibility for meaningful impact on decarbonization in the Cleveland-Elyria MSA. In principle, by significantly electrifying natural gas applications and process heating, accompanied by reducing the emissions of the grid as the region works towards a near net zero electricity, we can 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.[83] The combination of widespread electrification, demand for green hydrogen and potentially other fuels and chemicals, and changing heating and cooling requirements, the MSA's targets for renewable or net zero energy generation remain highly uncertain.

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.[84] 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 are already implementing 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 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. 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 had served the campus. These projects demonstrate the MSA is already willing and able to implement clean energy technologies.

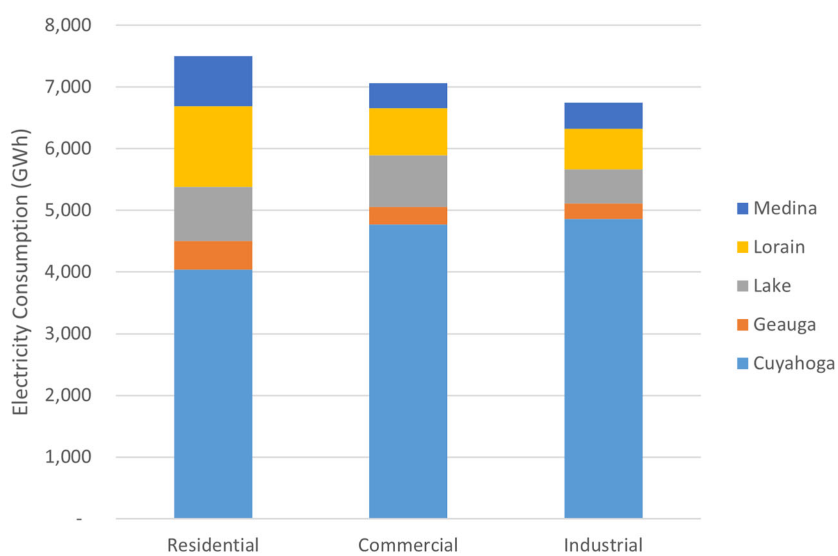
New or improved technologies are on the horizon, with significant potential to upend plans for this sector beyond 2035. New nuclear, enhanced geothermal electricity generation, and advances in offshore wind technology offer compelling technologies to close the gap on the energy transition. Additionally, 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 near term targets by 2030 in our region.

Electricity: In 2022, the region consumed approximately 21,310 gigawatt hours (GWh) of electricity.[85] Nearly all of that moved through the transmission system managed by FirstEnergy, and 87% came from FirstEnergy's distribution utilities, The Illuminating Company (CEI) and Ohio Edison (OE), while the balance was distributed through smaller public utilities, such as CPP. For much of the last 25 years, electricity consumption across the region has been relatively flat, with growth in some communities offsetting declining use in others.

The MSA's electricity use declined by 7.5% from 2018 to 2022.[86] 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.[87] 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 to their investors. With electricity demand now expected to grow, leaders across the MSA will need to intervene or more natural gas generation will be built.

Natural Gas: Natural gas is a key for heating, cooking, water heating 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 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.[88] Natural gas usage and accompanying emissions increased in the commercial and industrial sectors from 2018 to 2022, but decreased by 5% in residential energy use over the same period.

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



7.2.2. Challenges & Barriers to Decarbonizing Electricity Sector

Winter & Winter Peak Demand: Winter peak is the days during the winter months when extreme cold causes high grid energy demand. Technology combinations such solar photovoltaic (PV), combined with battery storage, can address the electricity requirements of summer peak, and the use of advanced geothermal energy for heating and cooling will address increasing and meaningful portions of the thermal requirements for our community and provide grid relief. However, winter peak events present significant challenges to decarbonizing using the lowest cost methods. Winter peak events already produce extremely high electricity demand and high prices, despite the use of natural gas for heating.[89] Additionally, the MSA experiences more than 200 cloudy days per year and an average of 88 cloudy days from December-March.[90] Solar output drops to just one-third of its peak July output in December and January, making it difficult for solar and storage to provide the MSA's wintertime power demands.[91]

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 if prices fall.

Dependence on Cheap Fossil Fuels: Ohio residents on average pay $0.1651 per kWh, nearly $0.03 and $0.05 cheaper than Michigan and New York, respectively.[92] This trend is tied to low natural gas prices, which remain low due to a lack of pipeline capacity to move natural gas from parts of the Marcellus and Utica Shale out of the region. Over time, these low prices have shaped prices, budgets and taxes in our region. With costs of new natural gas generation rising and wait times for new natural gas turbines increasing, the appeal of adding new low-cost solar at scale is expected to increase.[93] 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.[94] Painesville Municipal Electric will also close its aging coal-fired power plant and upgrade its municipal substation to better serve its customers.[95] This project provides Painesville and its partners, Cuyahoga County and the City of Cleveland, a way to act upon a central emissions reduction measure from the PCAP.

Perry Nuclear Power Plant: Perry was an early, key tool to help move the 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 ultimately only one reactor was constructed. The empty pad for plant two, 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 using 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.[96] 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 the Cleveland-Elyria MSA make immediate and sustained progress towards its 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 by purchasing clean energy. 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.

Community Choice Aggregation (CCA): Communities enroll in a CCA through SOPEC or NOPEC, energy aggregation organizations serving the MSA, to purchase 100% renewable energy for residential and small mercantile electricity 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 communities with LIDAC neighborhoods.

Opt-in Public Pricing Program (P3): Mercantile customers, including local governments, political subdivisions, non-profit and faith-based organizations, can take advantage of P3 programs. Within communities served by SOPEC, larger customers not traditionally served by CCA plans may opt-in to the 100% renewable energy agreement serving the community.[97] This program streamlines and simplifies enrollment, reducing barriers to renewable energy.

Power Purchase Agreements (PPAs): These contracts allows larger private sector companies and others not eligible to participate in CCA 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: Modernizing distribution system controls 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.[98] The substation built in Middlefield, Geauga 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[99]. By siting 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. Adopting energy efficiency measures, such as building weatherization and electrification, rely on proven technologies and are nearly universally 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 take 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.[100]

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

Residential Rooftop Solar: This measure is 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 CCA, rooftop solar mitigates against the risk of electricity price increases and allows the resident to maximize these low-cost electrons. The MSA can install 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 size of 17.25 kw per site. Accordingly, this measure can provide 418 MW by 2050.

Deploying large-scale solar is an important first step in decarbonizing the energy sector in the over the next 5 years. For every 10 MW of deployed solar, the MSA will generate 12,713 GWh of clean electricity. Further, initial large-scale deployments of solar + battery storage can significantly reduce summer peak demand on the electric grid, keeping the most-polluting electric generation assets off-line. Communities with abundant, developable rooftop space, surface or garage parking, or brownfields should pursue these opportunities early-on, as those with 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 integrating 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

For communities with relatively low solar radiance and high summer-winter variation - our MSA - the sizing and requirements for solar plus storage systems can be considerable if contemplating "grid independence." For these reasons, a stand-alone "solar plus storage" solution is not considered here 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 is expected to offer 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 may result in interrupted power – and the potential for brownouts.

7.2.4.5. District Thermal Energy

District Thermal Energy solutions will primarily be geothermal systems where sufficient land and geology permit. They may also derive their thermal energy from wastewater or industrial or data center cooling water in Legacy or Established Cities or in 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, while leveraging known technology, 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 deploying 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 MMTCO2e avoided.

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 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.

7.2.4.6. Long Duration Energy Storage

Storing renewable energy for long periods of time cheaply and effectively 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. While most hydrogen consumed within the MSA will be produced outside of the MSA, by 2040 we project having sufficient renewable energy capacity to support a 50 metric ton per day (MT/day) hydrogen electrolysis production facility (requiring 100 MW of renewable or zero emissions energy), and can add a further 100 MT/day facility by 2045 with new nuclear or geothermal electricity available to support this production.

7.2.4.8. Nuclear Energy

Key community and business leaders may enter into negotiations with the Perry Nuclear Power Plant to support the construction and completion of new nuclear reactors at the site. These

Perry Nuclear Power Plant. Source: Wikimedia Foundation.

discussions should include support for further extension to the lifetime of Perry Reactor 1. Nuclear power remains the best technology available today, and expected to be available to 2040, to meet electricity demand for winter months and especially winter peak events. Nuclear offers the additional benefit of having the highest capacity factor of any generation source, at 92.5%[101] 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 2046-2050.

U.S. EIA estimates that advanced nuclear power currently costs around $88 per MWh, though that cost could come down with tax credits.[102] As the region experiences a significant increase in demand for electricity, this price will 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.

Because Perry was designed for another reactor, it has the capacity to expand. This empty pad may be the single most significant decarbonization asset that the MSA has, 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 looking for clean, firm power will see the value of this facility. [103] New nuclear capacity could also enable the development of green hydrogen production in the region, which will be key for decarbonizing heavy industry, including steelmaking. Further support for nuclear energy should warrant close monitoring, and may become a point of advocacy if the Cleveland-Elyria MSA communities choose to support this technology and strategy.

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.[104] Despite earlier opposition, the available wind resource is too attractive to pass up, and this remains an important option for development after 2030. 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. Accordingly, MSA communities should pursue this option.

7.2.4.10. Geothermal Electricity Generation

Companies such as Fervo Energy are combining advances in drilling techniques with advanced heat-exchange technology to generate electricity at utility-scale plants.[105] The MSA finds itself on the periphery of ideal geologies for advanced geothermal solutions.[106] The 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.[107]

Other renewable energy technologies considered include Onshore Wind and Biofuels. Onshore wind is not ideally suited given the density of the MSA, the State of Ohio's wind setback rules, and the relatively poor quality of wind on shore in the region Biofuels grown from agricultural products grown in-region 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 to grassy perennial crops, especially miscanthus, for the purpose of producing biofuel.[108] 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. Capturing this waste heat to use as additional power generation or district heating could improve plant efficiency by 10-20%.[109] 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: The MSA's electricity demand is expected to triple by 2050. Approximately 66% of this electricity will be purchased from renewable or zero-emissions sources from outside of the MSA through CCA 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 MMTCO2e avoided in this sector by 2050. More aggressive timelines and capital investment would result in more emissions avoided, and should be considered.

Electrification and clean energy will create jobs and improve air quality by shifting away from burning fossil fuels. 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.

Benefits and Co-Benefits to LIDAC Communities: Of the GHG reduction measures, CCA is the easiest to execute, has the lowest barrier to entry, and is accessible to LIDAC Communities. 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 LIDAC communities through the aggregate reduction in emissions from fossil fuel combustion, the “brownfields to brightfields” strategy has the additional benefit of improving the land use for under-utilized or degraded sites, many of which are in or adjacent to LIDAC communities. Adding large solar power plants to these sites can result in local tax benefits, thereby increasing revenue for these communities.

Costs to the MSA: Costs for each GHG reduction measure are shared in the accompanying table, noting high degrees of uncertainty for technologies to be introduced after 2035. The adoption and deployment of rooftop and utility-scale solar offer the greatest clarity, with estimates for the average 3.45 kw rooftop solar system at about $9,000 per residence, with 30% investment tax credits (ITC) reducing costs significantly. Utility scale solar, with all-in estimates at $2 million per MW, offer similar clarity today.

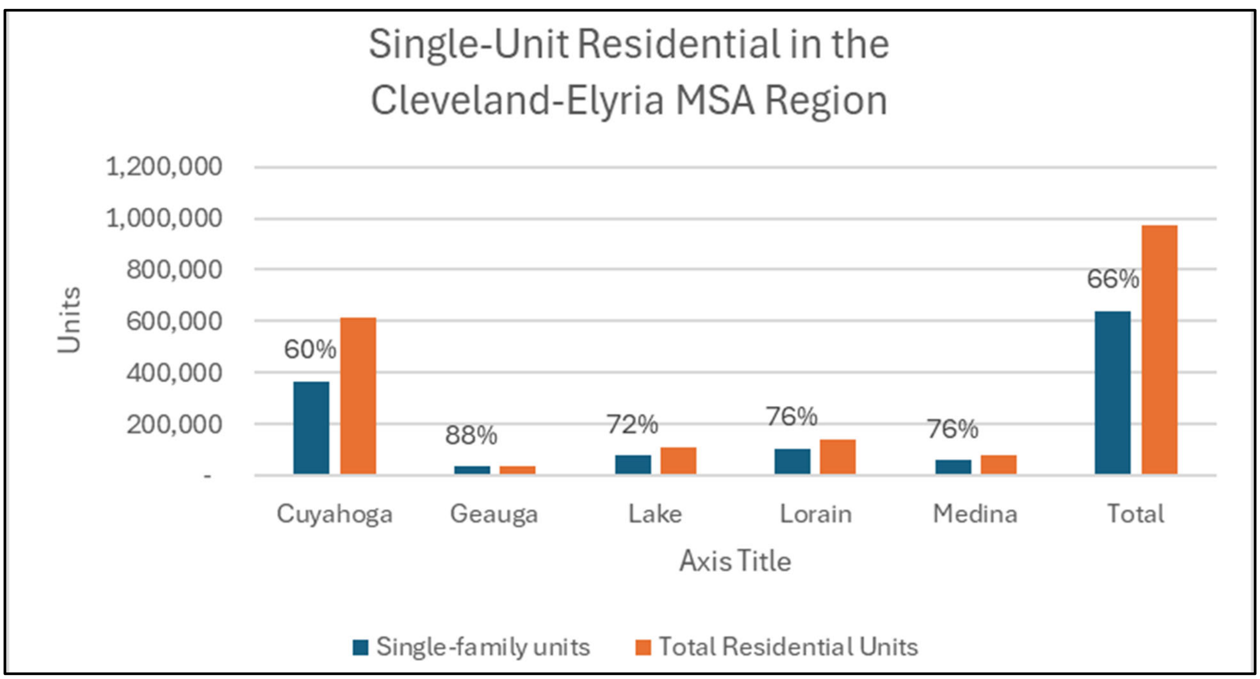
7.3. Residential & Commercial Energy Sector

The building sector (Commercial and Residential Energy) accounts for approximately 39% of GHGS in the MSA. While the majority of buildings in the region are residential, commercial properties account for roughly equivalent energy consumption. Decarbonization will require minimizing energy use and reducing the embodied energy of construction materials. The MSA can achieve this outcome by improving the building envelope materials and enhancing equipment performance while utilizing recycled, locally sourced, and low-embodied energy materials. The lowered energy consumption can be further offset through renewable energy sources, either at the home, community, or utility level.

7.3.1. MSA Context

The building sector is pivotal in the path toward regional decarbonization in the Cleveland-Elyria MSA. In this five-county region, 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 emissions reduction, advancing fairness, and economic development. The Cleveland-Elyria MSA's diverse housing stock 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, ensuring that the benefits of decarbonization reach all communities, particularly those historically underserved.

Figure 19: Residential Building Stock by County in the Cleveland-Elyria MSA



There are approximately 975,000 residential units in the MSA. The MSA has an aging housing stock, with the majority of residential units built more than 50 years ago. This aging 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 typically require substantially higher heating loads, increasing energy use, utility costs, and GHG emissions. Addressing the inefficiencies of this legacy housing stock is critical for advancing regional decarbonization and energy fairness.

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

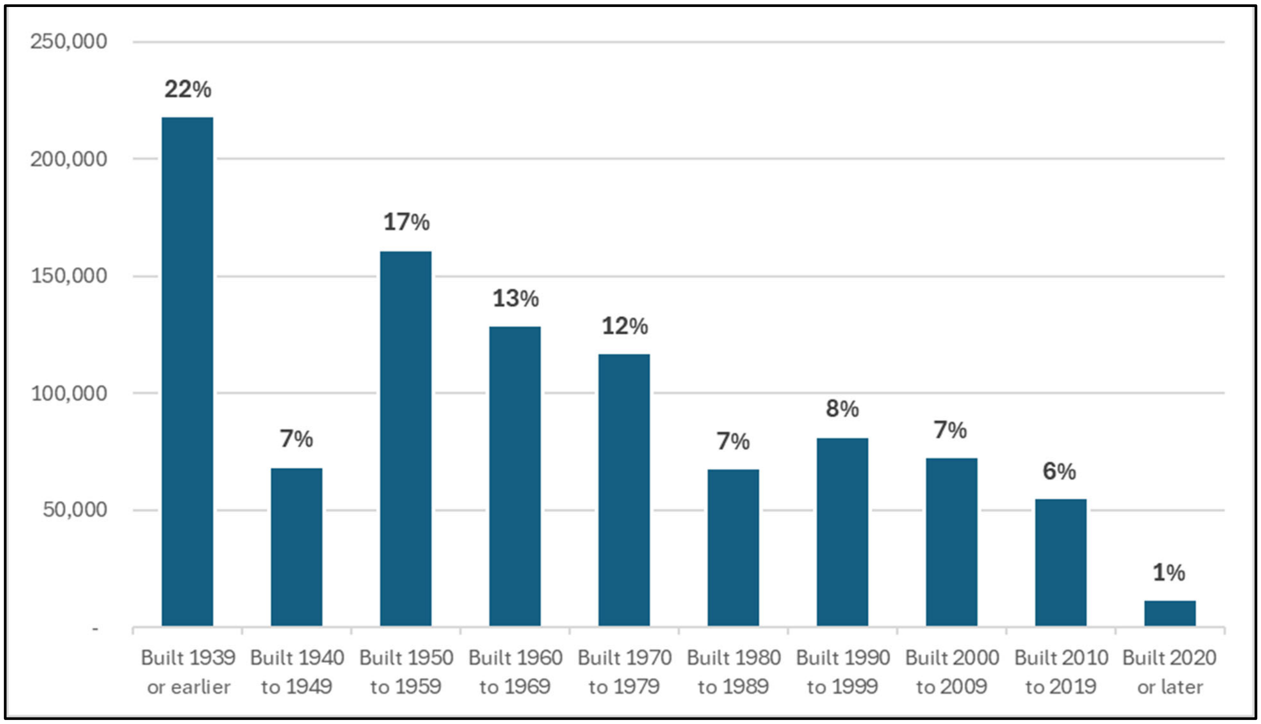


Figure 22 illustrates the MSA's dependence on natural gas for heating. Nearly eight in ten homes use gas, with a range of 59% in Geauga County to 81% in Lake County. This high consumption, particularly in older housing stock, underscores the urgent need for decarbonization efforts, as such homes typically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

The MSA's commercial and residential buildings produced a total of 11.7 $MMTCO_2e$ during 2022. Residential buildings accounted for the majority 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. Ensuring an equitable energy transition means prioritizing weatherization, renewable energy access, and financing mechanisms that address historical underinvestment in marginalized neighborhoods.

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.

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

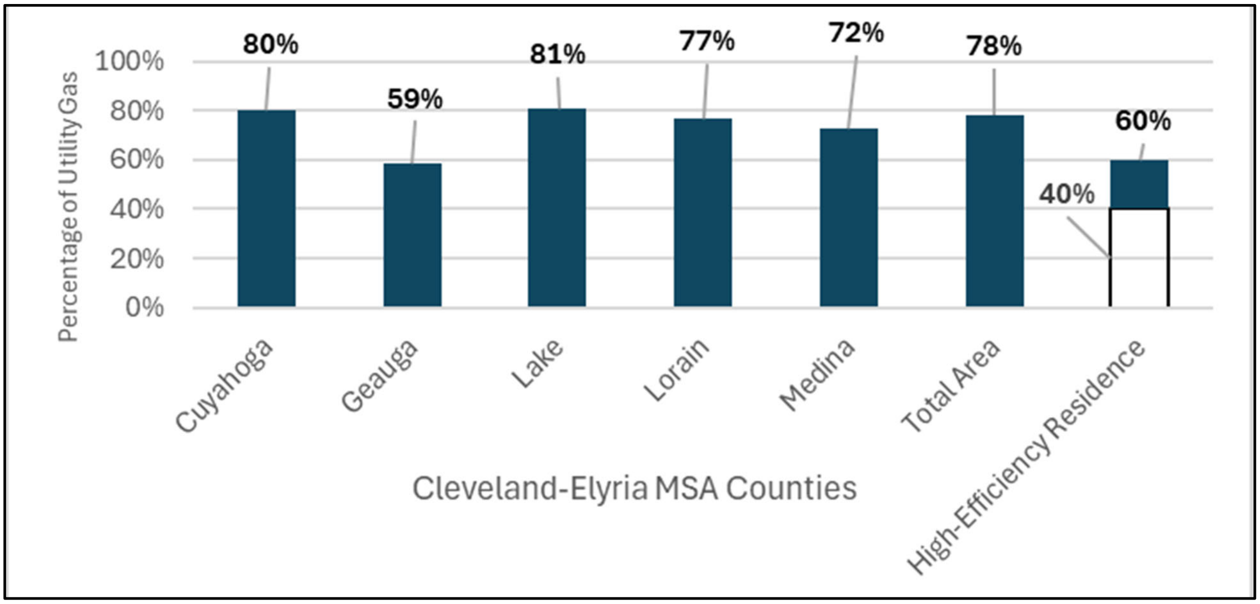
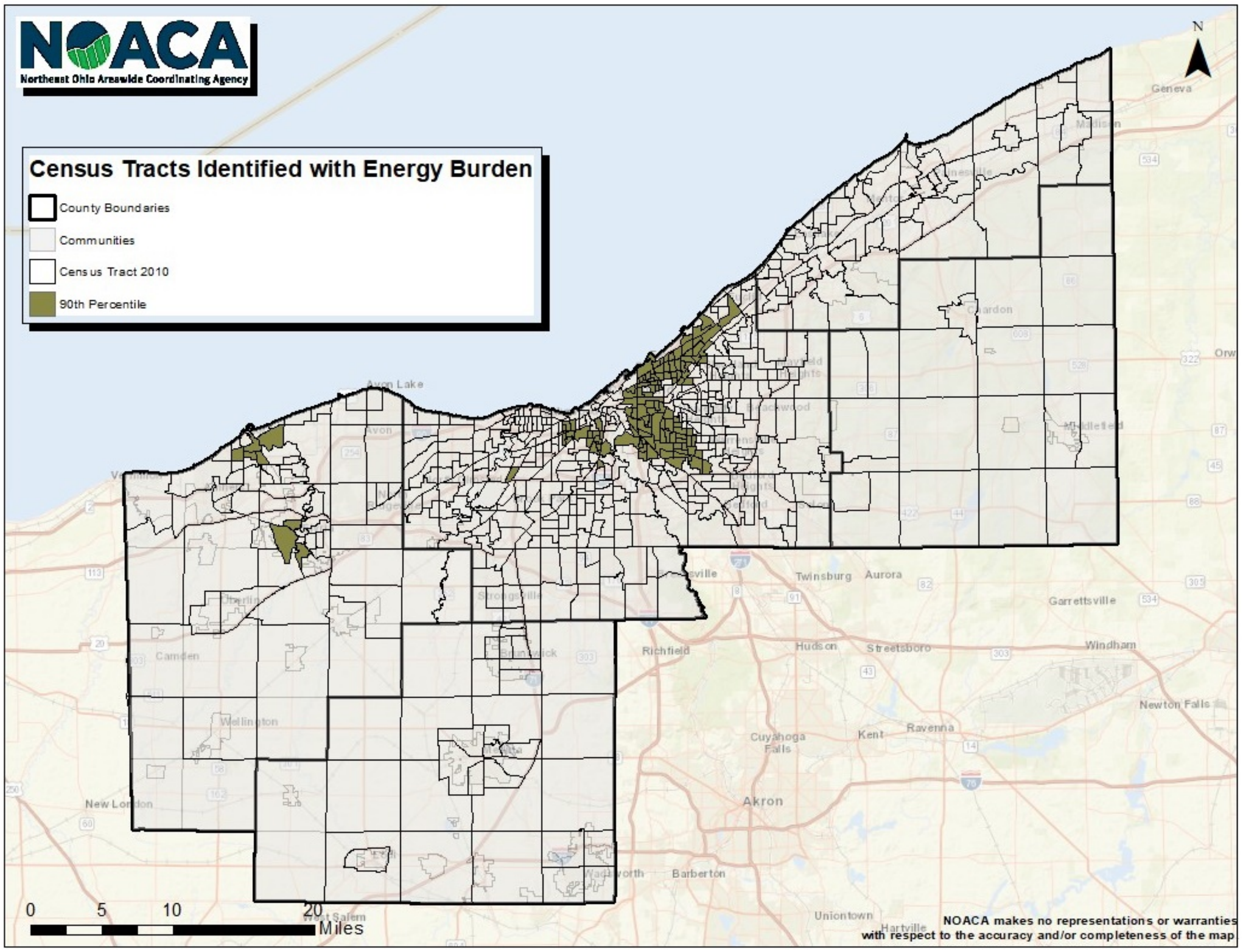


Figure 21: Census Tracts at or Above 90th Percentile for Household Energy Burden



7.3.2. Challenges & Barriers to Decarbonizing 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 the buildings in the area were built before the 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 multifamily housing.

Economic Constraints: Low-income residents often experience high energy burdens, with utility bills consuming 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 are responsible for paying 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. Decarbonizing commercial buildings 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 increasing challenges in Ohio.[110]

Technical and Workforce Limitations: There are significant technical and workforce challenges to scaling energy efficiency and electrification in the MSA.[111] There is a shortage of locally trained professionals with the skills needed for energy audits, heat pump installations, and weatherization work. Additionally, the lack of high-resolution, building-level energy data makes it difficult to identify priority buildings and develop targeted retrofit strategies, hindering effective planning and decision-making.

Fairness for Underserved Communities: Historically redlined neighborhoods and formerly 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.[112] 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.[113]

Electric Grid Readiness: The MSA's electric grid is not ready to support full building electrification. Much of the infrastructure is outdated and was 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 integrating 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.[114] These buildings represent a pressing challenge for regional decarbonization efforts.

Embodied carbon is already "invested" in vacant buildings. Roughly 20-40 tons of carbon is already stored in existing building materials, and this "disappears" when buildings are demolished. For comparison, rehabilitation retains 60-80% of this embodied carbon while generating only 8-18 tons of GHGs, creating a compelling case for rehabilitation over demolition.[115] Concentrated demolition patterns in distressed neighborhoods, such as Cleveland and East Cleveland, could reduce per-building emissions by 20-30% through equipment efficiency and coordinated transportation, while 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 generating 60-75% lower carbon emissions per building. Yet, while rehabilitation typically produces lower carbon emissions than demolition, the cost of retrofitting older vacant homes to achieve carbon neutrality may far exceed the building's market value, particularly in LIDAC communities. Decarbonization goals must be evaluated in the context of economic realities and community fairness.

Source: Oberlin College

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 combining 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 promoting 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 the use of rainwater harvesting and drought-tolerant landscaping. A pedestrian-friendly layout and shared amenities encourage walking and cycling, thereby decreasing transportation-related emissions and fostering a sense of community.[116]

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 slash GHGs. Its passive solar design is achieved through strategic building orientation and thoughtful daylighting, maximizing 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, offering 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.[117]

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 combining electrification, high-performance construction, low-carbon materials, equitable retrofits, and grid-interactive technologies. Key actions include replacing fossil fuel systems with heat pumps, adding on-site solar and net zero designs, and preparing for future battery storage with supportive policies. New buildings should exceed baseline codes using LEED, ASHRAE 189.1, and passive design. To cut embodied carbon, substitute conventional materials with mass timber, low-carbon concrete, and prefabricated systems, supported by 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 equitable 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 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 that will decarbonize this sector over the long-term.

7.3.4.1. Energy Efficiency Retrofits in Existing Buildings

Improving the energy performance of existing buildings starts with improving building envelopes and mechanical and control systems. Upgrading insulation levels significantly reduces thermal energy losses. Additionally, advanced framing techniques help minimize thermal bridging and improve overall wall performance.

Tightening the building envelope 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 areas where it is appropriate, enhance ventilation effectiveness while conserving energy.[118] Finally, incorporating occupant-responsive controls, such as daylight and motion sensors, ensures that lighting systems operate only when needed, thereby reducing unnecessary energy consumption. Together, these measures create a more efficient, comfortable, and sustainable indoor environment.

Implementing 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.

Commercial buildings in the MSA 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 result in a 40% reduction in energy use 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 reducing maintenance costs.

Policies to support energy efficiency retrofits include:

- Regional weatherization programs targeting pre-1975 homes;
- Advocacy for enhanced statewide energy code enforcement to require minimum retrofit standards during renovations;
- Adhere to the PCAP schedule milestones for retrofitting existing buildings with energy-efficient technologies to ensure timely and effective implementation;
- Integrating 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: Replacing gas furnaces and boilers with electric heat pumps that use ambient air or geothermal heat;
- On-Site Solar PV Systems: Promoting the installation of monocrystalline PV panels to offset electricity consumption;
- Net zero Home Design: Combining 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:

- 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;
- Supporting prefabricated net zero energy manufactured homes in the region;

- Expand the 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;
- Encouraging and supporting the establishment of construction materials recycling facilities in the region; and
- Proposed 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 regions need to encourage and incentivize developers to adopt higher standards such as ASHRAE 189.1, LEED, EnergyStar, or EPA GreenCheck. These standards adopt holistic approaches to promoting energy efficiency, reducing energy losses, and enhancing 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:

- Offering density bonuses or permit streamlining for developers building high-performance homes; and
- Proposing legislation that requires all municipal construction projects to adopt LEED or equivalent high-performance building standards, aligning these requirements with the Ohio Facilities Construction Commission (OFCC) mandate for public school buildings.

7.3.4.4. Low-Embodied Carbon Construction

Reducing embodied energy in buildings is a critical component of achieving 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 life cycle analysis (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 local (within a 500-mile radius) materials in building construction;

- Pilot low-embodied-energy construction targets for public housing and demonstration projects; and
- Integration of embodied carbon metrics in regional carbon accounting frameworks.

7.3.4.5. Grid-Interactive Buildings and Demand Flexibility

Integrating smart technologies into buildings plays a crucial role in enhancing energy efficiency and grid reliability. Smart thermostats and load controllers help reduce peak demand by adjusting energy use during times of high grid stress, and can be programmed to align consumption with the availability of renewable energy sources. Encouraging the adoption of 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, allowing 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;
- Partner with utilities to pilot residential demand response programs, contingent on the State of Ohio enabling regulatory frameworks that allow investor-owned utilities to participate and scale these initiatives effectively;
- 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, enhancing grid reliability, facilitating renewable energy integration, and reducing emissions.

7.3.4.6. Options to Fund Residential & Commercial Energy Measures

There exist a number of 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:

- Establishing public-private partnerships with local utilities, significant institutions, and philanthropic investors in the regions;
- Expanding the issuance of green bonds;
- Continuing to seek grants benefiting underserved communities in the region;
- Integrating clean energy investment with the Cleveland-Elyria MSA regional and county action plans;
- Collaborating with NOACA and regional development boards;
- Framing green projects as economic development initiatives;
- Creating demonstration funding focusing on rooftop solar at schools and workforce development initiatives; and

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

Measure Category	Measure Name	Cost Benefit	LIDAC Benefits
Energy Efficient Retrofits	Retrofitting homes 30 years and older (3 scenarios)	The total cost of the full implementation of the measure by 2050 is $8.55 billion, with a 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	Enhancing 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	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

		$6.3 million, with a 62-year Payback period.	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, is $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

Decarbonizing the residential and commercial building sectors the Cleveland-Elyria MSA 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.[119] 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. Implementing 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, illustrating the need for targeted workforce expansion initiatives the MSA.[120] 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, suggesting a pressing need for the region to proactively establish robust educational and inspection programs to train the next generation of building inspectors and code officials.[121]

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, ensuring broader economic participation in the transition to a sustainable energy economy. Leveraging partnerships with CBOs, religious groups, and local trade associations can enhance the inclusivity of workforce programs, thus promoting economic fairness across the five-county region.

7.4. Industrial Energy & IPPU Sector

7.4.1. MSA Context

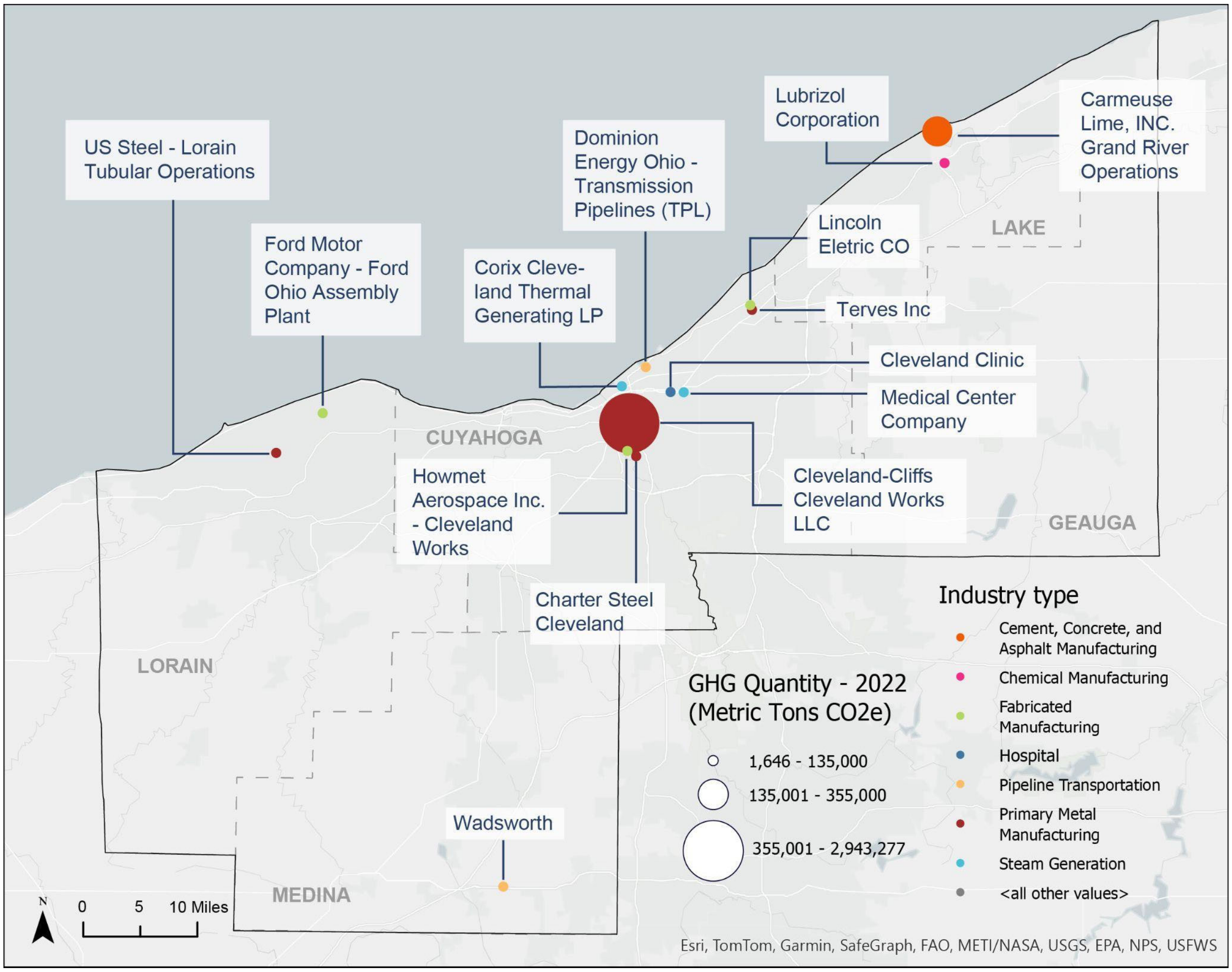
Decarbonizing the industrial sector is crucial to reaching net zero goals across the Cleveland-Elyria MSA. Industry accounted for 22% of the emissions in the MSA. This section describes actionable strategies and policies to decarbonize industry, focusing on eight of the most common point source emitters 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.

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 that have opportunities for decarbonization. Figure 24, below, shows the large industrial emitters in the region, with the color representing different types of industries and the size of the circle showing the relative quantity of emissions.[122]

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.[123] Based on data from the 2020 National Emissions Inventory (NEI), the main subsectors are: primary metal manufacturing, cement, concrete, and asphalt manufacturing, fabricated manufacturing, steam generation, chemical and plastics manufacturing, hospitals, pipeline transportation, and paper manufacturing.[124]

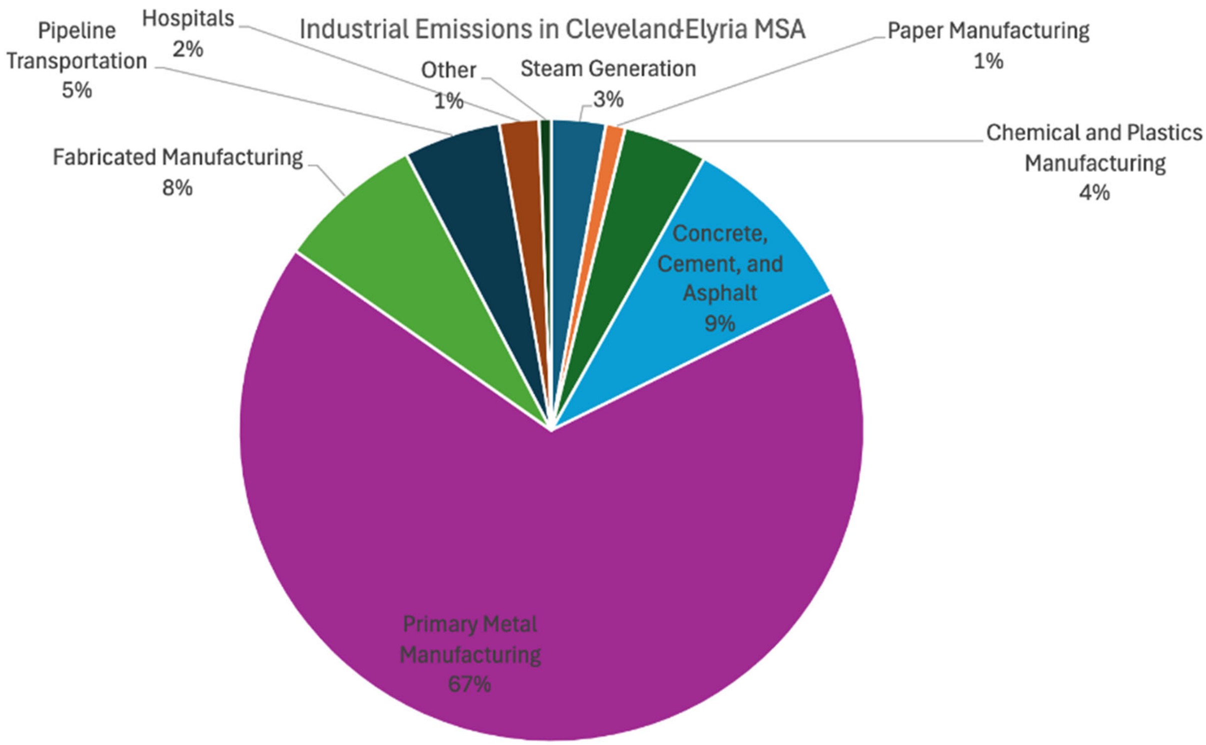
Cuyahoga County has emissions from most of the subsectors, but 89% of the industrial emissions stem from primary metal manufacturing or the iron and steel industry. In Geauga County, 71% of the industrial emissions are due to fabricated manufacturing from furniture manufacturing. Another large source of industrial emissions (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.[125]. 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 24: Large Industrial Emitter in the Cleveland-Elyria MSA



Source: U.S. EPA, "Facility Level Information on GreenHouse gases Tool (FLIGHT)"

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



7.4.2. Challenges & Barriers to Industrial Decarbonization

There are many challenges in decarbonizing 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 decarbonization solutions need to be tailored to each case. Financing is 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, adding to the risk of investment.

Additionally, many strategies depend on infrastructure that is not within the control of industry. To electrify heating processes, there needs to 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 maintaining the local economy.

This section highlights existing opportunities for aiding industries in decarbonizing as well as recommending a benchmarking strategy that encourages local industries to decarbonize.

7.4.3. Local Success Stories & Opportunities

Many industries in Cleveland have taken real measures towards achieving real sustainability measures. Cleveland-Cliffs' oily wastewater treatment plant employs chemical flocculation (CF)

Cleveland Works Facility, Source: City of Cleveland

electrocoagulation (EC) to treat oily wastewater before release. These processes lead to significant cost savings and environmental benefits.[126] Lubrizol, headquartered in Wickliffe, is committed to sustainable chemical engineering. The company has reduced its scope 1 and 2 GHG emission by 21%, has 13 sites using 100% zero-carbon electricity, and has reduced its waste-to-landfill by 25% 2018.[127]

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. Establishing HVAC setbacks that decrease air exchange rates, converting to LED lighting, and manually powering down resources at day's end have saved the Clinic 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.[128] 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 enable 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 measures to provide a fuller suite of measures that will 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 a number of measures that also address the remaining one-third of industrial GHGs.

There are seven overarching strategies for decarbonizing industry, based in part on the US Department of Energy (U.S. DOE) *Industrial Decarbonization Roadmap*.[129] Those strategies are: Energy Efficiency, Process and Material Efficiency, Electrification, Alternative Fuels, Renewable Energy, Carbon Capture Utilization and Sequestration (CCUS) from point sources and directly, and New Industry Support. DAC is another regional solution that can supplement these measures.[130]

7.4.4.1. Industrial Energy Efficiency

Beyond the decarbonization benefits due to using fewer energy resources, energy efficiency saves money and reduces waste. While the specific application of energy efficiency methods vary across subsectors, measures include conducting energy audits, installing energy monitoring systems, upgrading to energy efficient equipment, automating processes, combined heat and power systems, and waste heat or steam recovery systems.

Energy Audits: Energy audits establish a baseline of 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.[131] Conducting an energy audit 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. Ensuring that the proper sized motors, pumps, fans, etc. are being used for the process being done could save up to 15% electricity.[132] The U.S. DOE also offers its Better Plants Program to connect industrial partners with national lab-based technical account managers who can consult on energy efficiency and decarbonization strategies that best fit the facility.[133]

Monitoring Systems: Installing 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%.[134] Digital monitoring equipment gives real-time updates on energy consumption and can give insights into where settings could be optimized. This allows for better energy management, consistency in operations, and reduced energy consumption.[135]

Energy Efficient Equipment: Energy efficient equipment depends on the industry subsector and are discussed in more detail in the appendix, 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%.[136]

Automation: Installing automatic shutoffs for when equipment isn't in use reduces the emissions from idle power consumption and can reduce electricity consumption by 5-10%.[137] Using 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.[138]

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 by 20-30%.[139] 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.[140] Adding heat recovery systems to processes could recover significant amounts of waste heat that can be fed back into the original heating system, could be used in other processes, or could be used in combined heat and power systems.[141] 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 up to 20-30%.[142] Alternatively, insulating heating process lines like gas lines, steam pipes, and molten metal transport systems prevents heat loss in the first place and improves heating efficiency, leading to 5-10% reductions in heating energy.[143]

7.4.4.2. Process & Material Efficiency

Process and material efficiency reduces 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: To reduce transportation emissions, 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%.[144]

Recycle Materials: Instead of designing items for single use in cradle-to-grave frameworks, all industries should consider potential secondary use for their products, designing them in a cradle-to-cradle framework, whether by identifying opportunities to recycle materials within their own industry or by establishing partnerships with other industries.[145] Recycling single-use drums and other containers can reduce waste and associated costs as well as raw material demand.[146] Recycling water reduces energy demand due to pumping new water in and out and reduces the amount of treated oily wastewater being released into the local watersheds.[147] Installing internal gas capture and recycling systems, especially in industries where high GWP gases are used will minimize quantities of fresh gas flows and reduce fugitive emissions.[148] Implementing onsite closed-loop recycling systems to reuse scraps produced in manufacturing processes can reduce the quantity of raw materials needed and can reduce emissions by 10-15%.[149]

Automation: Relying on manual inventory management is inefficient. Automated storage and inventory optimization with artificial intelligence can improve space utilization and decrease energy usage by 10-15%.[150] Automation can optimize workflows by improving efficiency, optimizing material usage, and minimizing waste. This reduces process errors, material waste, and energy consumption, cutting energy use by 5-10%.[151] 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.[152]

Process Changes: There are many opportunities for reducing energy and material consumption through redesign of processes, implementing innovative techniques, or switching to biobased or less environmentally harmful materials. Many processes can evaluate their heat consumption through energy auditing. Some processes may need a lower volume or temperature of steam than they currently are being supplied. Identifying whether there are process changes, opportunities for redesigning processes, or existing equipment settings to reduce steam demand can lower fuel consumption.[153]

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.[154]

Additive manufacturing may not be suitable for all fabricated metal manufacturing applications, but it is a process that effectively 3D prints metal components, reducing material usage by up to 50% and cutting heating emissions.[155] Thin slab casting of steel involves pouring thinner layers of steel rather than rolling out thicker slabs of steel. This process, while requiring major facility upgrades costing around $50 million, could lead to up to 75% in energy savings. [156]

There are also opportunities to switch what type of material is being used from high energy or GWP materials to relevant alternatives. Some inhaled anesthetics have high GWPs.[157] Using lower-GWP anesthetics (e.g., sevoflurane) and switching to a policy of regional anesthesia when appropriate, followed by using intravenous anesthetics, when possible, will reduce emissions by 5-10%.[158]

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.[159]

7.4.4.3. Industrial Electrification

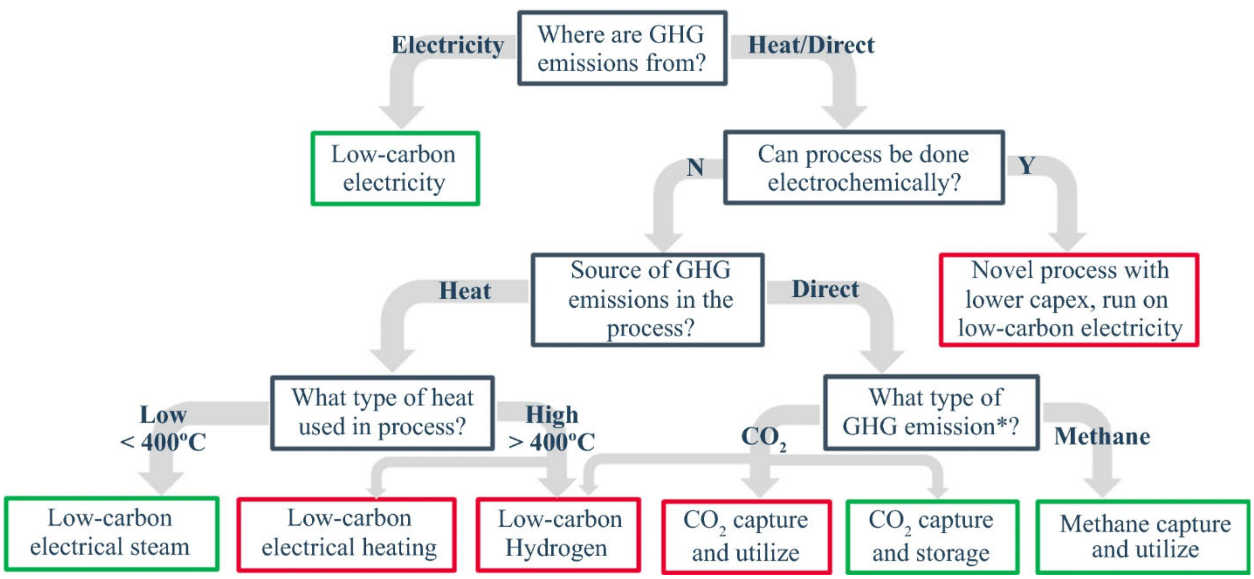
Electrification involves switching current processes to electric versions of those processes. There are two central opportunities for electrifying industry: process heating and machine drives. The U.S. DOE Electrified Processes for Industry without Carbon (EPIXC) supports innovative projects that aim to electrify process heating.[160]

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 by 45-70% depending on the specific process.[161] High temperature processes, however, need more time for development and deployment, but by 2050, thermal storage, multi-process heat pumps, electric boilers, resistive heating, inductive heating, or microwave heating will be commercially viable for higher temperature processes as well.[162] Figure 26 shows a decision tree to aid in determining whether the heating process can be electrified. Highlighting the distinction between fossil fuels being burned for process heating versus the process itself. In the case of the process itself, alternative fuels or carbon capture must be considered.

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 Hydrogen based Direct Reduction (H_2DRI) and EAFs. This process is currently being used in Sweden with a technology called HYBRIT (Hydrogen Breakthrough Ironmaking Technology), and Volvo is testing the steel for automotive purposes.[163] Right now, it does not make commercial sense to entirely switch because making H_2DRI is extremely expensive due to the price of hydrogen and the cost of construction.[164] This system, which provides a path to decarbonization, should be commercially viable for replacing both BF-BOFs at Cleveland Works around 2040. Alternatively, the BF-BOF could be replaced with molten oxide electrolysis (MOE) by 2050.[165] 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 H2 production, transportation, and storage onsite, and can use lower grades of iron ore than DRI can use. Boston Metal is working on a demonstration plant set to open in 2026 to showcase commercial viability of the technology.

Figure 22: Electrification Decision Making Tree



Source: Eryazici et al, 2022.

Machine Drives: Industry also uses fossil fuels in operating machinery in compression, grinding, milling, or pressurizing. Electric alternatives consume less energy than traditional systems and could lead to at least 10% emissions reductions.[166]

7.4.4.4. Alternative Fuels

Where fossil fuels are used for the industrial process itself electrification cannot serve as a replacement, meaning alternative fuels must be considered. 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.[167] Chemical manufacturing uses fossil fuels as a feedstock for chemical reactions. These are cases where electrification cannot replace the chemical reaction taking place. To move away from a dependence on fossil fuels, alternatives such as green H_2, biomass, consumer waste, or manufacturing waste can be used as feedstocks.[168]

As noted, H_2DRI and EAFs can decarbonize integrated steel production. This would be a massive investment, as it would require H_2 to either be produced onsite (50 kg H_2 per ton of steel) or transported 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.[169] Cliffs can begin converting to DRI now, as switching from coke to natural gas DRI can provide a bridge to full green steel production.

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 as well as highlighting 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, installing carbon capture technology to the flue gas system can reduce total emissions of the cement sector by 65%.[170] For industries where CO_2 makes up 10% or more of the exhaust gas, CO_2 could be captured through scrubbers at rates of up to 95% capture efficiency.[171] The CO_2 concentration is crucial for making capture economically feasible, and the higher the concentration, the more economic sense it makes to capture it.[172] 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, like sequestering it in cement.[173] The Industrial Appendix offers a detailed study of incorporating carbon capture at the Cleveland Works existing facility.[174]

Direct air capture: DAC takes CO_2 from the air at a rate 100 times more land efficient than reforestation. The technology currently exists but is expensive and requires large amounts of clean energy to operate.[175] Regional DAC facilities co-located with sequestration sites or CO_2 utilization industries would help to 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.[176] This is not only an opportunity for new industry creation but also serves as a way to cover gaps in meeting net zero goals throughout the rest of the MSA. Current technologies can capture 500,000 MTCO2e per year, but this will likely improve by 2050.[177]

Utilization: Once captured, CO_2 can provide feedstock for carbon-based chemical production in a closed-loop manufacturing process.[178] 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, making the concrete stronger and sequestering the CO_2.[179] There are also specialized industries that are developing unique uses for captured CO_2 streams, such as sustainable aviation fuel.

Sequestration: Even upon reaching 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.[180] The remainder of captured emissions will have to be geologically sequestered. For such large volumes of CO_2, pipelines are expected to be the most economical and efficient mode of transport.[181] In addition to having enough capacity to store the volume of CO_2 captured, a suitable storage site must have sufficient 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 has to be spent overcoming resistance to fluid flow during injection. A detailed case study for capturing CO_2 at Cleveland-Cliffs' Cleveland Works Blast Furnace, along with an evaluation of potential pipeline routes, and potential locations for geological sequestration is in the Technical Appendix.

7.4.4.6. Industrial Renewable Energy

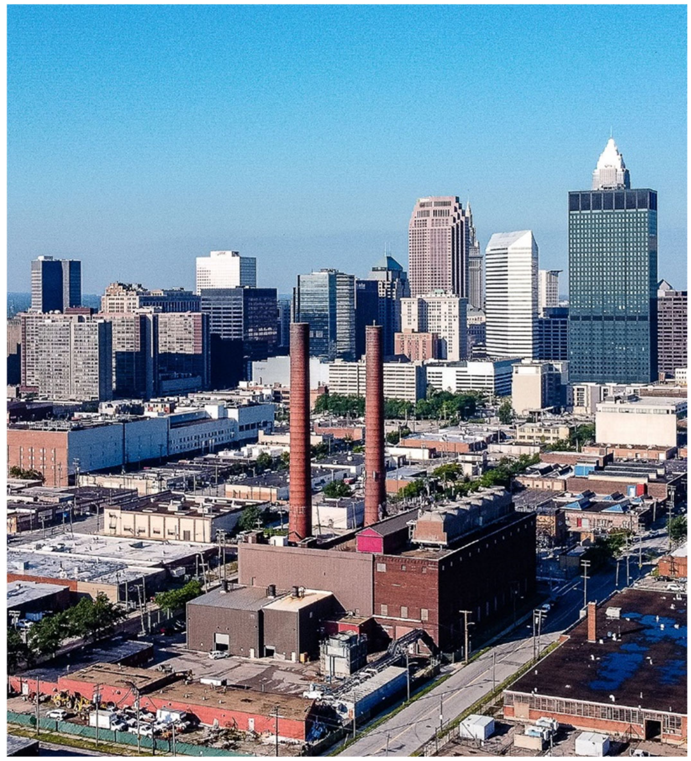
Increasing the amount of onsite energy production at industrial facilities would reduce electricity costs, improve electricity resiliency, and can reduce the grid impact of electrifying industries. This section focuses on combined heat and power (CHP) systems and converting district heating to district 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.[182] There are currently no examples of CHP systems used in industrial applications in the MSA outside of Cuyahoga County, but CHP systems should be considered for other manufacturing applications.[183]

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. Retrofitting existing district heating for geothermal district heating that utilizes geothermal energy would remove the reliance on natural gas-powered steam generation, drastically reducing emissions.[184] 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 their network to a water-based network by replacing existing steam lines with insulated hot water pipes, replacing steam-based radiators, and upgrading control systems.[185] Additionally, geothermal resources would have to be established, which involves drilling boreholes and installing ground heat exchangers to transfer thermal energy between the earth and the district energy system.[186]

7.4.4.7. New Industry Support

Decarbonizing industry offers many opportunities for new industries to emerge in Cleveland-Elyria MSA.



Corix Cleveland Thermal, Source: Corix

Electric Heating: Electrifying process heat is crucial for decarbonization, as heating is the largest source of industrial emissions.[187] 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 locate here.

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.[188]

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 carbon capture, transport, and sequestration, there are many 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 comes opportunities for CO_2 utilization, and encouraging a utilizer to locate 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 are showing ways to utilize captured CO_2, such as sustainable aviation fuel, sequestering CO_2 in cement, solid long-term storage fuels, and creating electricity from ions that are produced in absorption of CO_2. [189]

Data Centers: Increased demand for data storage, cloud computing, and artificial intelligence is expected to continue, with the U.S. DOE projecting a nearly 8% increase in electricity consumption due to data centers by 2028.[190] There is much guidance on ensuring comprehensive design and placement of these data centers to ensure that their energy consumption is renewable, they utilize natural cooling sources, and there is heat recovery incorporated in the design.[191] One potential use for waste heat captured from data centers would be to use it for preheating in industrial applications.[192] 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 23 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

Decarbonizing industrial processes and operations has many benefits in addition to a reduction in CO_2. Other, more harmful emissions can be abated, directly improving public health, electrification reduces noise and vibration making work environments safer, improvements in water usage efficiency decreases the amount of industrial waste water, and new industrial support will create new job opportunities in the region that are discussed in depth in the Workforce Planning Analysis section (Chapter 12).

Public Health: To quantify the health benefits of reducing industrial pollutant emissions, 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.[193] Table 24 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 with the total reduction of these emissions can be found in the appendix.

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	$4,370,000
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 at the average human pain threshold. [194] 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.[195] Replacing equipment with electric alternatives would make safer work environments and surrounding communities by allowing workers to better hear one another and protect them from noise levels that are dangerous in themselves.

Water Quality Improvements: By improving resource management at a facility, investing in more efficient machinery, and installing water recycling systems and leak detection equipment, facilities can reduce the amount of water consumed and reduce the amount of polluted water returning 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.[196] In 2023, they also began to install a skimmer that reduces water consumption by 23 million gallons per year.[197]

7.5. Transportation & Mobile Sources Sector

Transportation and mobile sources accounted for 29% of GHGs within the Cleveland-Elyria MSA during 2022. Making this sector more efficient, accessible, and environmentally sustainable is critical for decarbonizing the MSA. 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 automobiles culminating in the Model T, to the rise of rideshare platforms such as Uber, disruptive innovations have continually reshaped transportation—overcoming barriers and delivering widespread benefits.

7.5.1. MSA Context

Two priorities form the foundation of transportation decarbonization: 1) reducing vehicle miles traveled (VMT) to move people and goods; and 2) transitioning to zero-emissions vehicles (ZEVs) and fuels.[198]

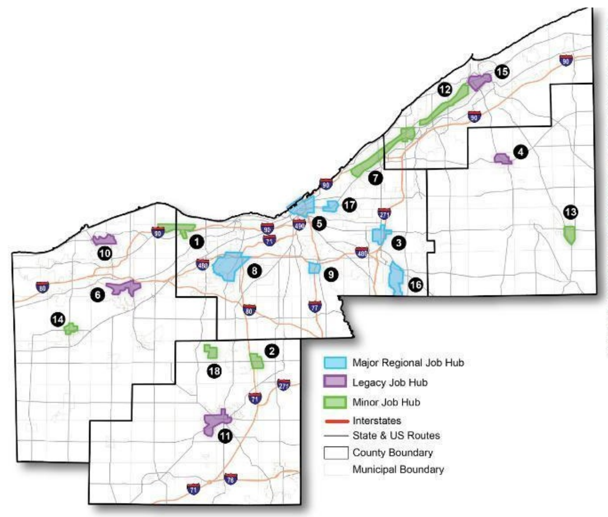
Reducing VMT centers on making transportation more convenient, through system-level design strategies that provide easy access to employment, community services, and recreational opportunities, aiming to minimize unnecessary travel while fully addressing mobility needs. Local and regional land-use decisions and the way communities and mobility networks are structured affects travel choices. Reducing emissions and improving safety, traffic flow, and overall quality of life requires thoughtful land-use planning, more efficient freight logistics, and the adoption of emerging practices such as telecommuting and the collaborative economy.[199] 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 transit naturally gain traction, the driving remains the dominant mode throughout the Cleveland-Elyria MSA, as it remains the quickest, most convenient form of travel.

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. According to NOACA, each of the MSA’s six major job hubs is located in Cuyahoga County, which attracts the majority of home-based work trips from its neighboring counties. The MSA’s highway system, which was built to accommodate a significantly larger population, makes it easy for people to drive to these job hubs.[200]

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 decreasing 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.

Figure 23: NOACA's Major Regional Job Hubs



Enhancing the 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 deploying ZEVs, particularly BEVs and hydrogen FCVs, and low-carbon fuels. Achieving a net zero economy will require transitioning new vehicle sales to zero-emission technologies across all modes of transportation and rapidly converting 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 Decarbonizing Transportation

Significant obstacles to decarbonizing transportation 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, making hub-and-spoke transit systems less effective and complicating cross-county commuting. Population shifts from the urban core to suburban communities strains 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.

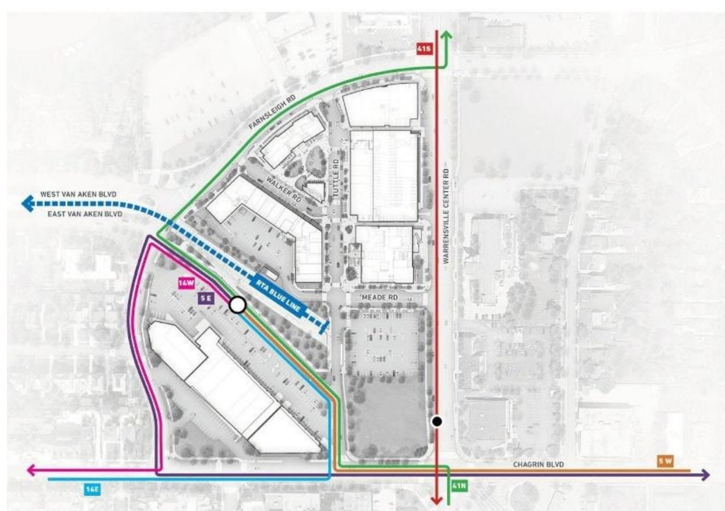
The MSA faces several critical decision points in its transportation decarbonization efforts, including: whether to prioritize VMT reduction versus vehicle electrification; how to allocate finite funding between maintenance and new infrastructure development; whether to focus development along existing transit corridors or expand service to growing suburban areas; and determining appropriate governance structures for regional transportation planning. The MSA cannot depend on state support as ODOT is focused on higher-growth regions of the state.[201] 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.

Parts of the MSA are experiencing 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. However, market forces and infrastructure investments continue to push development outward into the region, resulting in disinvestment and population loss in some city neighborhoods, on-going suburban expansion, and job dispersal.

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 much of the 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, creating safety hazards and maintenance challenges. Communities may need to adapt infrastructure by adding 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

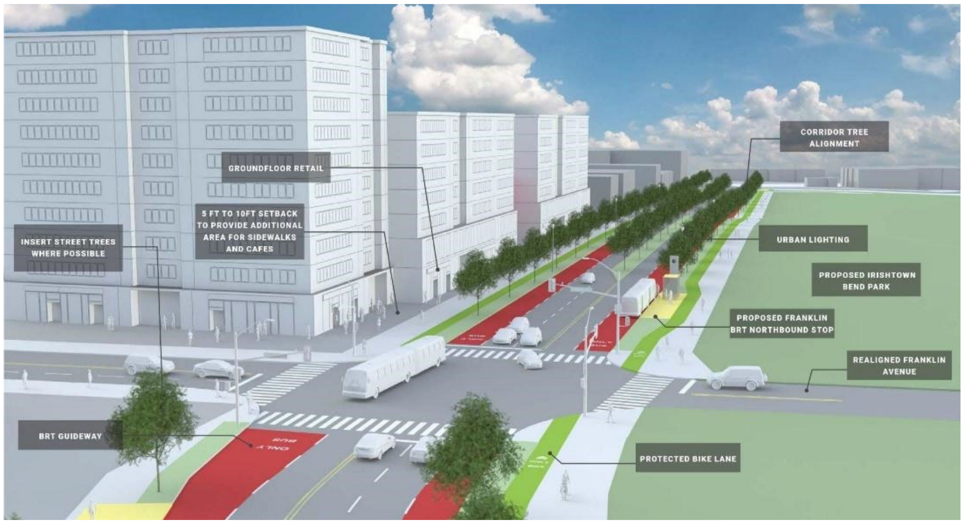
Several local projects demonstrate how transit-oriented development, combined with the adoption of cleaner transit vehicles and charging infrastructure, can reduce VMT and GHGs. Together, these efforts illustrate how coordinated planning and low-emission transit solutions can offer replicable models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



Source: The Van Aken District

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 replacing single-story retail. The co-location of uses in a compact area enables VMT reduction, allowing the development to significantly reduce transportation emissions through increased transit ridership, reduced trip generation through mixed-use development, and active transportation.

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 the course of years. The area is anchored by 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.



West 25th Street Bus Rapid Transit, Source: GCRTA & Stantec

The neighborhood features pedestrian-friendly design with wide sidewalks, street trees, crosswalks, and traffic calming measures, plus a diverse mix of land uses within close proximity. The area has successfully preserved its historic character while accommodating new growth, maintaining authentic neighborhood feel through public gathering spaces like Market Square Park and offering a range of housing options from renovated historic buildings to new mixed-use developments.

Two nearby public housing estates—Lakeview Terrace and Riverview Tower—play an important role in maintaining economic diversity in the area, as they provide stable, affordable housing options that help anchor lower-income residents in a rapidly changing neighborhood. Though affordability remains a challenge and represents a common issue with TODs, the proximity to public transportation does provide transportation cost savings for lower-income residents who've been able to remain in the area, partially offsetting housing cost increases.

Lorain County Microtransit: The cities of Lorain and Elyria have partnered to launch an innovative on-demand microtransit service, improving 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. Using multimodal trip planning features via app, riders can connect to jobs, schools, and other destinations. Lorain County Transit has expanded the program to provide additional demand-response services, including Dial-a-Ride and the Oberlin Connector, with plans to further expand ViaLC further as a core component of the county's transportation network.

Electric Transit Buses: Transit providers in the MSA are making progress toward cleaner fleets by deploying battery electric buses and charging infrastructure. In Lake County, Laketran has emerged as a statewide leader in electric transit. In 2021, the agency deployed ten new 35-foot BEV buses—transitioning 60% of its local fixed-route fleet to ZEVs.[202] 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.[203] 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 the 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.[204] 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

The following sections describe a full suite of emissions reduction measures from across the Transportation and Mobile Sources sector, which will enable the Cleveland-Elyria MSA make immediate and sustained progress towards its GHG reduction targets. These measures largely correspond to the VMT Reduction, Light Duty Vehicle Electrification, and Heavy Duty Vehicle Electrification measures from the PCAP; however, this section builds upon that priority measures to provide 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; thus, the CCAP adds measures to address aviation, nonroad vehicles, rail transportation, and waterborne transportation

Strategies and actions for this sector are grouped according to whether they address transitioning to cleaner vehicles and fuels or VMT. TOD has among the highest GHG mitigation potential of any VMT reduction measure.[205] As such, it forms its own distinct category of emission-reduction measures within the transportation sector.

7.5.4.1. Transition to Cleaner Vehicles & Fuels

Two-thirds of these 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 (0.9%).[206]

The following section highlights measures for addressing 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 for decarbonizing 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).[207] 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.[208]

Public education and outreach: Effective education and outreach campaigns are essential for familiarizing 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 expand these efforts by hosting their own public demonstrations and developing 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.[209] A comprehensive outreach campaign with 8-15 events across the five-county region would likely cost between $250,000 and $300,000.

Accelerate electrification of LDVs by increasing 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. By aggregating demand across hundreds of cities, counties, transit agencies, school districts, and other government units, the Collaborative enables participating jurisdictions to access competitively bid pricing on EVs and charging infrastructure.[210] This collective purchasing power not only 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, enhancing the capacity of local agencies to transition fleets strategically.[211] Expanding participation in this initiative across the MSA would allow 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: Regardless of the availability of federal tax credits, there are several use cases for local governments—including patrol cars and panel cargo vans—where BEVs are at cost parity with

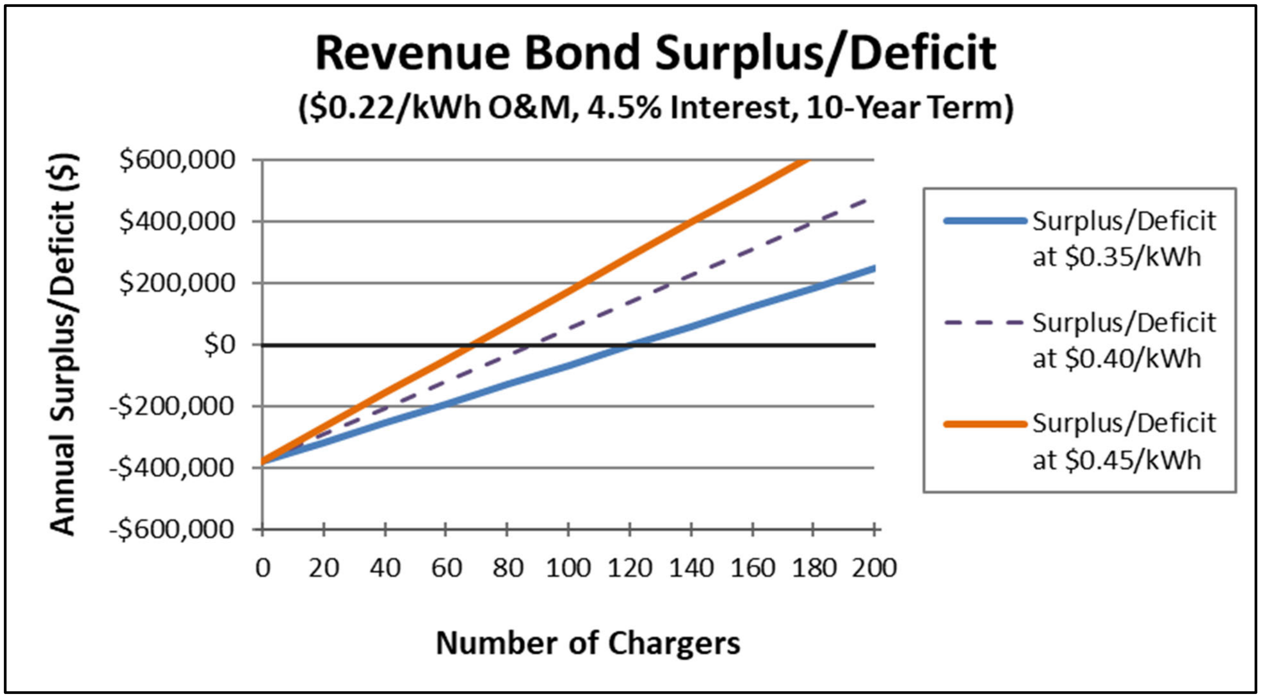
ICEVs.[212] EVs have operation and maintenance costs and require less downtime.[213] A 2024 study estimated that annual maintenance costs for light-duty EVs in Cleveland would be 53% less than an equivalent ICEV.[214] More precise and standardized estimates of EV useful life across vehicle classes and 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.[215] By 2050, NOACA's travel demand model projects an LDV population of nearly 2 million across the MSA. To meet regional decarbonization goals, 99% of these vehicles would need to be electric by 2050.[216] This transition requires the EV stock to grow by 21% annually.[217]

A local EV rebate program could help meet this goal. Rebates are especially effective when delivered at the point of sale through participating dealerships, rather than requiring consumers to apply for reimbursements or wait for tax credits.[218] 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 household by 21%, aligning with the regional growth rate needed for full electrification.[219] To be effective across a range of household incomes, a rebate of at least $2,000 is likely necessary, given EV pricing trends.[220]

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 carrying 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 25 and 26 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.[221]

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

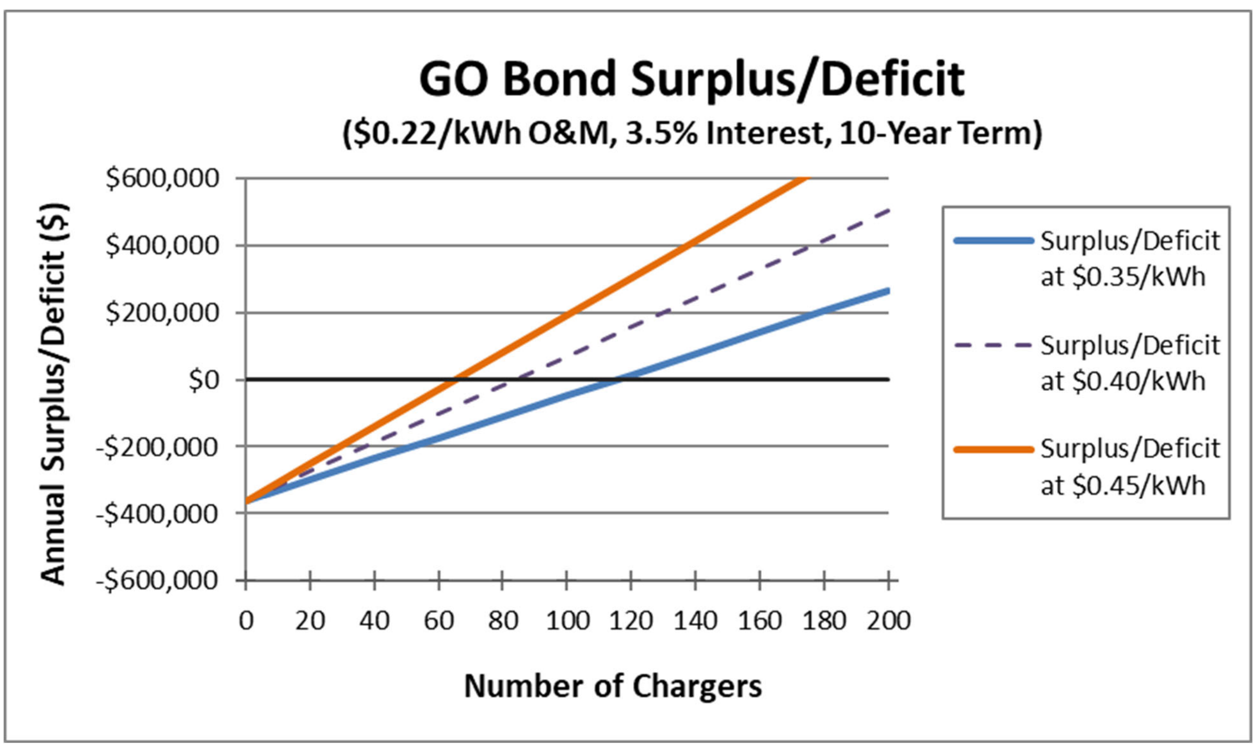


Figure 24: Annual Surplus/Deficit from Public EV Charging (Revenue Bonds)

*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 2050 would require the cumulative development of around 37,000 and 2,400 public Level 2 and DC Fast charging ports, respectively.[222] A charging network at this scale would require $358.3 million in cumulative investment through 2050.[223]

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. Coordination 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 by making public land available or co-developing hubs for multiple fleet operators. Public-private partnerships offer a path to scale, with municipalities providing 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 using public fleets—such as transit buses—can demonstrate use cases and generate valuable data for broader planning. Finally, 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 that use 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.[224]

Design: New airplanes could be more efficient through their structure and materials used. New plane designs with longer, thinner wings could reduce drag significantly, reducing fuel burn by 10-30%.[225] There are projects developing composite airframe technologies that will make aircraft lightweight, reducing the amount of fuel needed.[226] Other projects are focused on determining whether more of the powertrain on an aircraft can be electrified.[227] Finally there is software that models aircraft performance, allowing for more environmentally focused aviation design.[228] Encouraging the adoption of these new designs will significantly reduce 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 (SAF) that have 94% lower life cycle emissions than traditional jet fuel.[229] SAF is effectively a direct substitute for jet fuel, requiring the same amount of SAF as jet fuel as is currently used.[230] Currently, only up to 50% blends of SAF are allowed in aircraft, but by 2030, 100% SAF should be able to be used, with the goal of adopting 100% SAF by 2050.[231] There are programs that support the transition to SAF such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), with the goal of reducing emissions on international flights to a baseline through SAF, and Lower Carbon Aviation Fuel (LCAF).[232] While SAF does not need to be manufactured within the region, establishing strategies for obtaining the necessary quantities of SAF will be crucial.

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.[233] DOE lists four strategies for decarbonizing ports and ships involved in the maritime transportation sector: electrification, alternative fuels, optimization of technology, and efficiency strategies, which will reduce emissions from the maritime sector by 95%.[234] 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 is taking electrification seriously, receiving a $95 million grant from the EPA for an electrification initiative that will install electric charging infrastructure, support electric ground transportation equipment such as forklifts, installing an electric heavy-lift harbor crane, building two electric tugboats, and preparing warehouse A for solar installation.[235] The Port of Cleveland needs 5-7 MW to completely electrify port operations, and the solar installation will cover 2 MW of that solar.[236] This is a significant undertaking and smaller ports could adopt these strategies at a much smaller scale. The DOE is supporting the development of battery electric boats across most marine vessels, but electrification is only expected in supporting short trips for harbor craft such as ferries and in non-commercial vessels by 2050.[237]

Optimization of Technology: Establishing vessels with low friction bottom coatings can reduce the amount of fuel needed to propel a ship by 10%.[238] Ports can provide power to ships during loading and unloading to reduce emissions from auxiliary fuel consumption while idling in port.[239]

Efficiency Strategies: Establishing best practices within the port and in the transportation of cargo broadly can reduce the amount of fuel used by ships and reduce the emissions from other transportation sectors. Inland towing by tugboats can reduce emissions from trucks by 9 times and trains by 1.4 times.[240] Improving traffic flow to reduce idling time within a port can reduce emissions by 20%.[241] Reducing vessel speeds in ports also can reduce emissions by around 40% depending on the vessel type and fuel used.[242]

Alternative fuels: By 2050, the DOE projects that the majority of marine vessels will use sustainable alternative fuels for maritime vessels such as biodiesel.[243] 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.[244] The ships entering and exiting 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.[245] 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.[246] Full adoption of alternative fuels in the maritime sector is anticipated by 2050.[247]

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 needed, however, building the catenary lines costs around $71,000 per mile, making it traditionally cost prohibitive.[248] Alternatively, battery electric rail transport is viable, however delays due to charging and range limits make them less attractive.[249] Combined frameworks of these two types of electrification allow for batteries to take-over when there are no catenary lines, and utilize regenerative braking and other efficiency methods.[250]

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 could be used instead.[251] Otherwise, electric alternatives should be adopted as they are three times less expensive than hydrogen.[252] 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.[253]

Operational Efficiency: Rail operators can cut emissions immediately by reducing idling, optimizing scheduling, using dynamic train braking, and implementing real-time analytics for efficient routing. These changes can reduce emissions by up to 20% and support longer-term technology transitions.[254]

Non-Road Vehicles: Non-road vehicles, which include forklifts, construction equipment, and airport ground support vehicles produced 76,200 $MTCO_2e$ during 2022. Of those emissions, 57% come from diesel engines, 31% comes from gasoline, 11% comes from liquefied petroleum gas, and 0.1% comes from compressed natural gas.[255] Decarbonizing non-road vehicles is possible through a combination of energy efficiency strategies, electrification, and the adoption of alternative fuels.

Energy Efficiency: Upgrading to high efficiency equipment (dredgers, conveyor belts, hoists), or retrofitting existing, fossil fuel dependent equipment with energy-efficient motors, variable speed drives, and automatic shutdowns can save 10-15% energy and reduce emissions by 5-10%.[256]

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 decarbonizing, completely eliminating emissions from this equipment.[257] Construction equipment, ground transportation for warehouses and airports, open pit mining equipment, and facility forklifts can all be electrified.[258] 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.[259]

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 for transitioning 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, improving mine safety.[260] While equipment varies, the average non-road equipment requires around 10 kg per hour of operation.[261] Some operations may find hydrogen fuel cell electric forklifts more suitable, but currently the trend is a greater uptake in battery electric forklifts.[262]

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

Targets for VMT reductions in the near term include a 15% reduction in passenger vehicle miles traveled 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, 15% of all trips could be conducted via walking, cycling, or public transit.

Measurement: A critical first step is already underway. NOACA has established a consistent VMT measurement methodology across all five counties to ensure accurate tracking of progress including:

1. Unified data collection framework
2. Consistent calculation procedures
3. Standardized emissions calculations
4. Governance and quality control
5. Detailed Procedures

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 seniors. 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.[263]

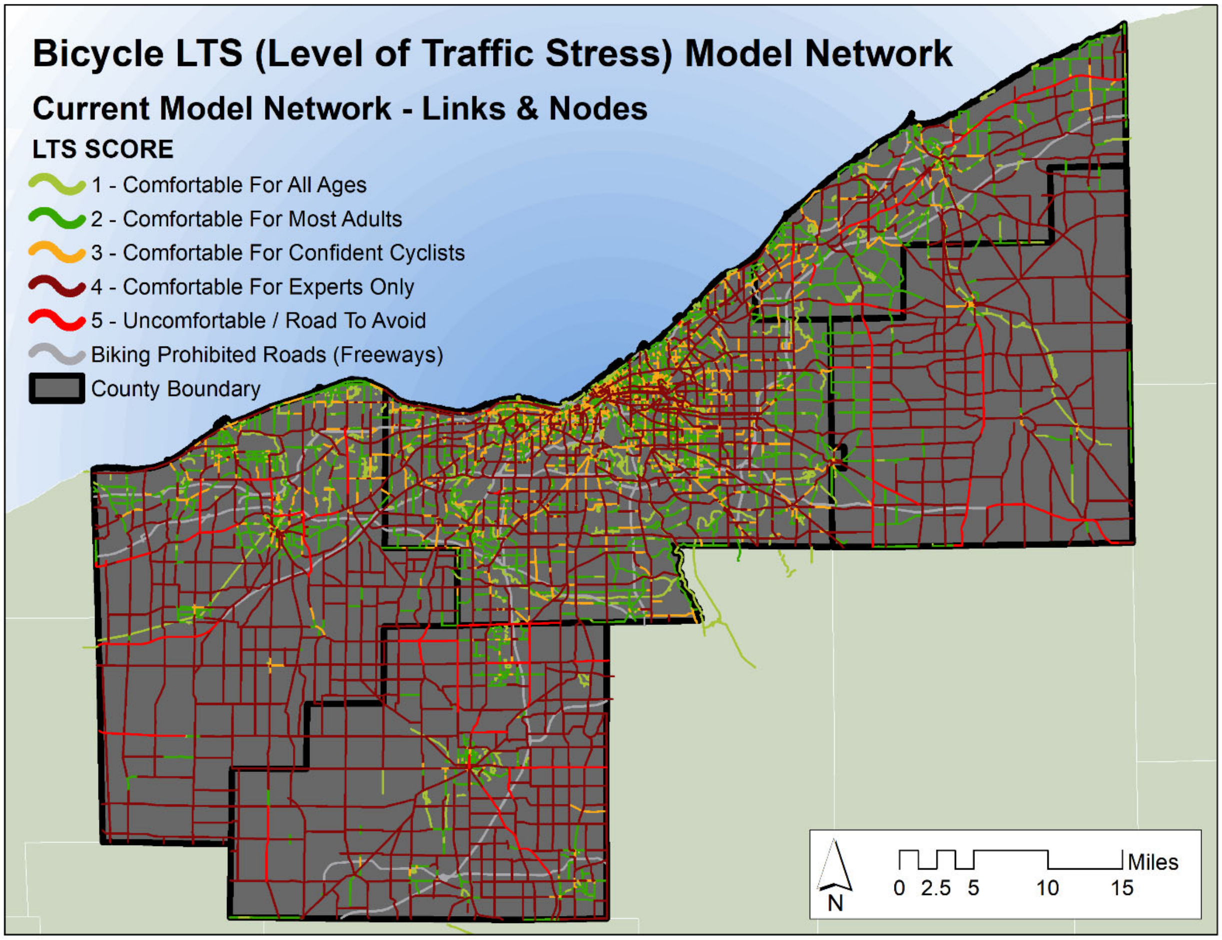
NOACA's ACTIVATE Plan maps levels of traffic stress (LTS) across the MSA, noting that the most fundamental improvements to the region's bicycle network would be to create connected bicycle lanes with a LTS of 1 or 2. Low-stress connectivity can be used to evaluate and guide a bicycle network expansion. In 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 crossing 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 the local streets.[264]

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 of completing 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 are also expanding bicycle infrastructure. These investments will help to establish best practices that can be replicated in other communities in the MSA, including:

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

Figure 30: NOACA Bicycle Level of Traffic Stress Model Network

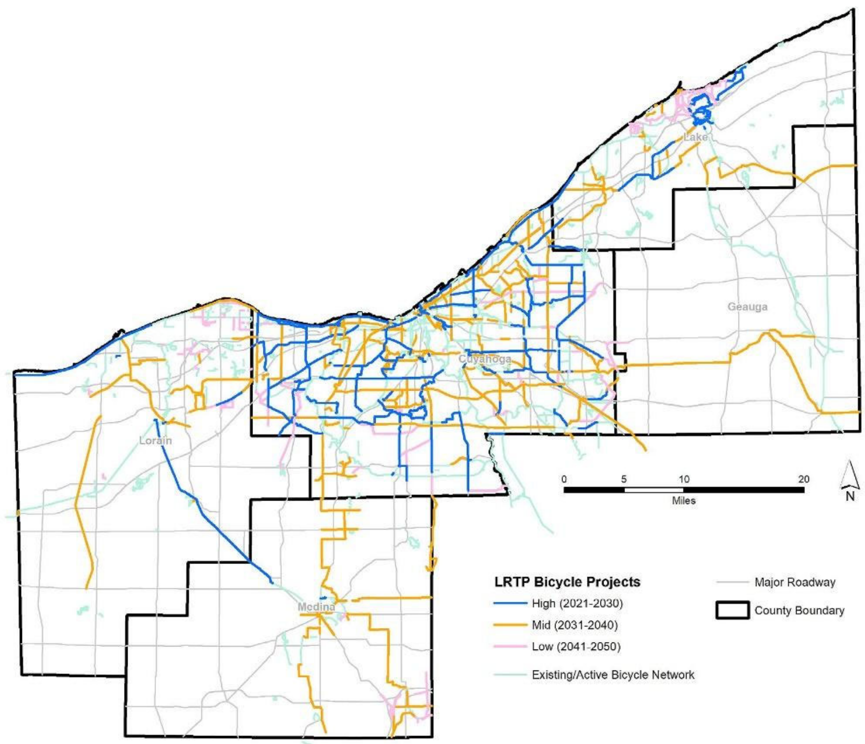


There tend to be fewer bike facilities in the outlying areas of the MSA; however, several communities have invested in bike infrastructure, including:

- 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, *eNEO2050*, incorporates existing and planned bicycle projects to enhance regional transportation and mobility. 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

Figure 31: Existing and Planned Bicycle Projects (eNEO2050)



incorporates recommendations from the Vibrant NEO 2040 plan, which focuses on enhancing walking and cycling as transportation options.[265] A notable current project, the Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Plan, is designed to connect bicycle infrastructure with existing bus routes, facilitating last-mile connections to public transit.[266]

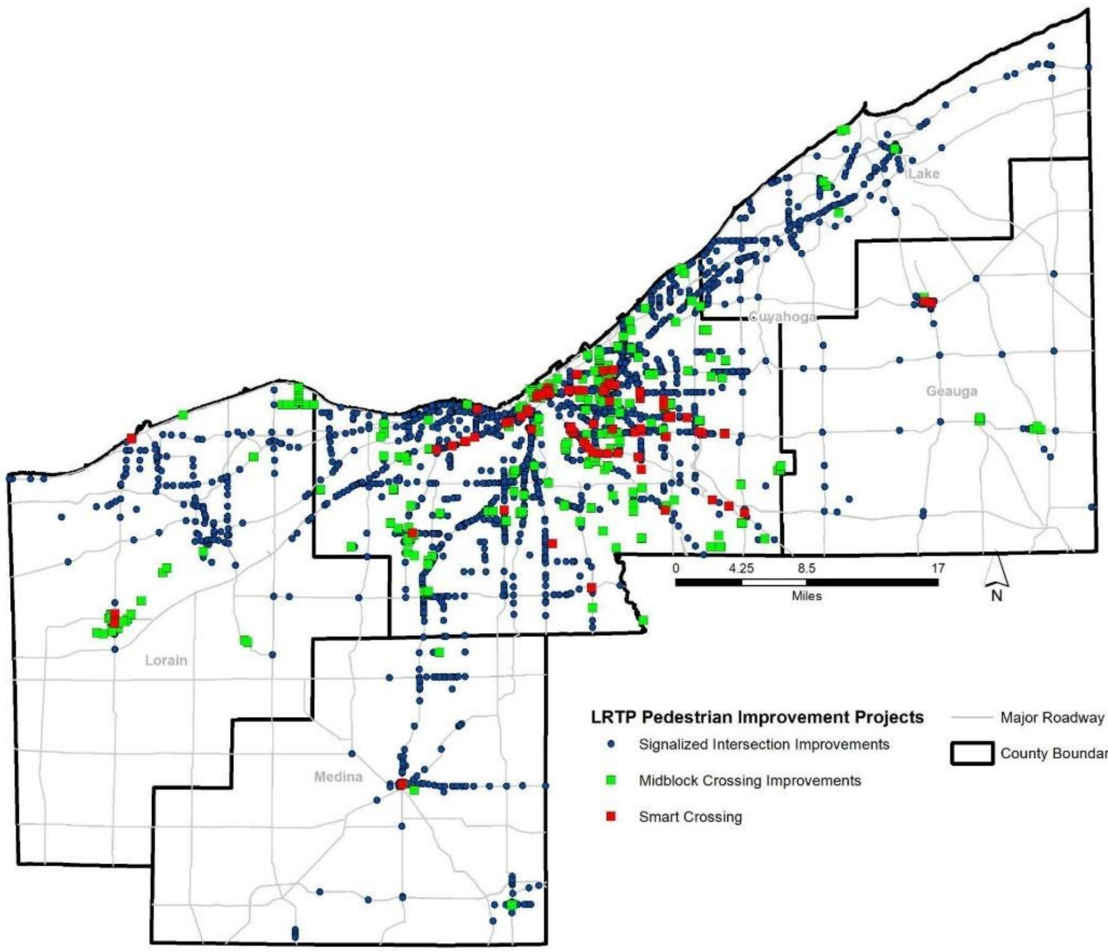
Bicycle infrastructure depends on connectivity. Currently, many bike facilities across the MSA exist as isolated segments, which limits their utility. New bicycle infrastructure projects should aim to connect to at least two existing facilities, in order to create a more usable network that can reduce 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 while maintaining network functionality. Filling the gaps between disconnected segments and shifting to more protected bike facilities should be a priority for the region in order 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 winter 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. To enhance pedestrian comfort and safety, a maximum crossing distance of 30 feet should become standard, unless the street design includes a pedestrian island.

eNEO2050, NOACA's long-range plan, includes existing and planned pedestrian projects, aimed at improving pedestrian safety and connectivity, while also fostering a more equitable and sustainable transportation system for Northeast Ohio. *eNEO2050* 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 (eNEO2050)



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 for improving pedestrian infrastructure and expanding 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 by reducing 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.

eNEO2050 includes a scenario that focuses on building a comprehensive multimodal transportation network centered on public transit. The foundation of this approach is an enhanced regional rail system based on 2017's visionary rail network plan that would expand the number of rail stations in the MSA from 50 to 162, and extend rail service east and west to create access in places such as Solon and Medina and increase walkability to stations.

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 to 45 minutes or less via public transit. To support this transit-oriented approach, the plan encourages housing development near transit stations and major job centers, with a specific target of having an additional 1% of the region's 2050 workforce living 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 by:

- Converting all revenue buses to non-diesel (mostly CNG) by 2035.
- Expanding an electric bus pilot to 20 buses. Fleet electrification should be a priority for all transit providers in the region, although as noted in the section on local success stories, Geauga Transit and LakeTran have focused on propane-powered buses to reduce emissions and fuel costs.
- Phasing out gasoline fueled non-revenue and paratransit vehicles, replacing them with hybrid and electric.

Strengthening Regional Connectivity: Currently, only 12% of transit routes cross county lines, despite an increasing percentage of employment opportunities requiring intercounty commuting.

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)

Building on the foundation established in the first five years, the 2030-2040 period could include more ambitious goals for the region. Passenger VMT could target a 25% reduction from baseline levels. This would be a substantial acceleration from the previous decade. Freight VMT could aim for a 10% reduction through combined efficiency improvements and modal shifts to rail and water transportation. If alternative fuel adoption reaches a critical mass in this time 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.

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

Figure 33: The Six Es of Transportation Safety

Regional connectivity could become a reality through the implementation of five intercounty transit connections providing 30-minute peak service, effectively linking employment centers, educational institutions, and commercial districts across jurisdictional boundaries. These connections would build upon early successes from the 2025-2030 period while expanding service frequency and coverage area. Major transit nodes should include robust micro-mobility options—including 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 standard ensures that 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 such as on-board racks or dedicated storage areas.

Comprehensive Active Transportation Networks: Implementing "Vision Zero" policies across all five counties would establish a region-wide commitment to eliminating 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. *SAVE* adopts the vision that traffic deaths and injuries can be prevented with appropriate planning, policies and programs, with a long-term goal of reducing the number of fatalities and serious injuries by 50% by the year 2040. Achieving a safer transportation network requires addressing the interaction among the infrastructure, vehicles and the skill and behavior of travelers. The SAVE Plan incorporates a "6 E's" approach into the safety planning process, acknowledging the key roles that engineering, education, enforcement, emergency response, evaluation, and equity all play in preventing severe crashes and saving lives.

Establishing ten 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 that create vibrant, walkable public spaces that support local businesses and community interaction.

Legacy Cites and First-ring Suburbs should create continuous pedestrian networks, extending 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, allowing for seamless bicycle commuting between residential areas and employment centers. Outer-ring suburbs could focus on implementing eight-foot multi-use paths along 100% of connector streets, accommodating 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 also improving roadway durability and safety for all users.

The mid-term period could culminate in the completion of a 150-mile regional protected bicycle network connecting all county seats with high-quality, all-weather bicycle infrastructure linking urban centers, suburban communities, and rural areas throughout the MSA. The network could follow scenic corridors where possible, serving both transportation and recreational purposes while showcasing the region's natural amenities and strengthening 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%, representing 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.

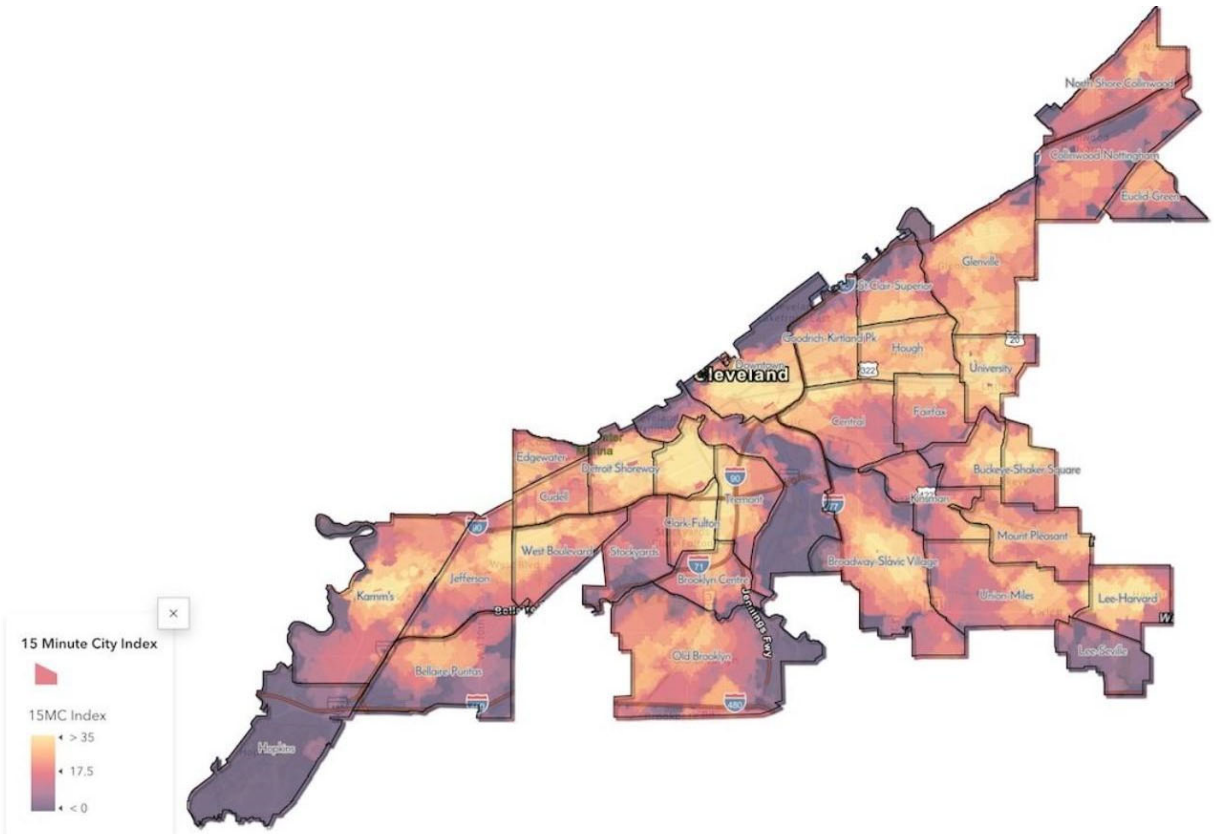
Sustainable Funding Mechanisms: The long-term strategy should include a fundamental shift in transportation funding models. The region could establish VMT-based taxation systems to replace gas taxes, with differentiated rates for freight and passenger vehicles, given their varying impacts on infrastructure and emissions. ODOT has convened discussions on this issue, but implementation would require statewide action. This approach would provide sustainable revenue as vehicle efficiency increases and alternative fuels become commonplace. Additionally, comprehensive road pricing mechanisms based on time of day, location, and vehicle occupancy might be implemented, creating financial incentives that could 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 level of service (LOS) metrics to alternatives, in partnership with ODOT, under its Vulnerable Road User Assessment, fundamentally reshaping transportation project evaluation.[267]

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 reconnecting Cleveland 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.

Figure 34: City of Cleveland 15- Minute City Index



The Cleveland City Planning Commission has adopted a 15-minute city model. 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, potentially including automated transit vehicles operating on dedicated guideways within major corridors. These systems would provide higher frequency, lower operating costs, and improved reliability, compared to traditional transit. 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.

Systems Transformation: The transformation of work patterns will likely continue, with potentially up to 50% of office workers adopting remote or hybrid arrangements that significantly reduce commute trips. 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. New residential construction should be focused on areas of the region that are well-served by public transit in order to achieve reductions in VMT. This is already occurring, at least in parts of the MSA. For example, one-third of new development in Cuyahoga County from 2019-2024 occurred in TODs.[268] Development regulations could require VMT-neutral outcomes for all new construction, meaning that any project generating additional vehicle trips would need to implement mitigation measures that offset this increase. These measures might include funding for expanded transit service, constructing bicycle infrastructure, providing affordable housing near employment centers, and contributing to regional mobility services.

7.5.4.5. Transit-Oriented Development (TOD) Opportunities

TOD is an effective approach for reducing vehicle miles traveled while simultaneously enhancing quality of life and economic vitality. The Cleveland-Elyria MSA, with its existing transit infrastructure and diverse community typologies, has opportunities to implement TOD strategies that are tailored to local contexts. The region’s well-established development patterns will not change quickly, but the following approaches occur over time.

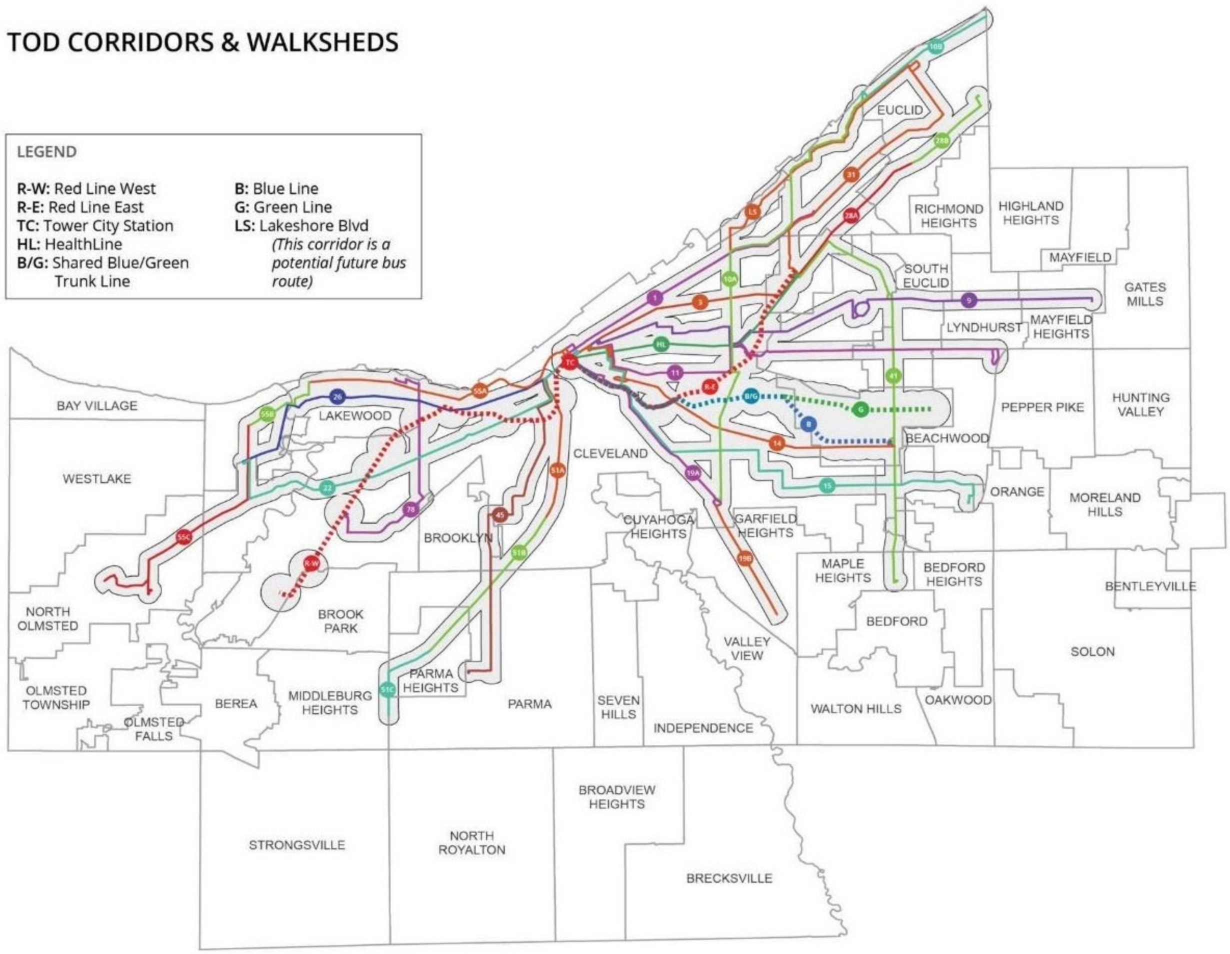
Corridor-Based Development: Development should be strategically focused along key transit corridors that connect major employment centers, educational institutions, and cultural destinations. These corridors include existing rail and BRT lines and potential future BRT routes. Targeted zoning updates will be essential for focusing development around rail stations and major bus stops, while maintaining 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. Building on this work, the Cuyahoga County Planning Commission completed a TOD Study, which includes a Model TOD Zoning Overlay. Collectively, these studies, plans, and tools lay a solid foundation for TOD projects in Cuyahoga County and throughout the MSA.

Cross-Jurisdictional Coordination: Many transit corridors cross municipal boundaries, creating 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. Implementing 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.

Figure 35: Cuyahoga County TOD Corridors



Anchor Institution Partnerships: The Cleveland-Elyria MSA benefits from numerous major institutions, including world-class universities, healthcare systems, and cultural organizations. Leveraging these anchor institutions as partners in TOD implementation would accelerate progress significantly. These partnerships, which already exist in University Circle and could be replicated in other parts of the region, include employer-assisted housing programs, 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 leveraging existing transit assets and preparing for future expansion:

- Public land inventory and strategic disposition: Identify publicly-owned parcels within a half-mile of high-capacity transit stations and develop strategic disposition plans prioritizing affordable housing and mixed-use development.

- TOD overlay districts: Establish TOD overlay districts in key station areas that reduce parking requirements, streamline approval processes for projects meeting TOD criteria, and incentivize affordable housing inclusion.
- Anchor institution housing initiatives: Using the established Greater Circle Living initiative[269] in University Circle as a model, partner with major employers along transit corridors to 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.
- Tax increment financing districts: Establish TIF districts around key transit stations to capture value and reinvest in infrastructure improvements that support walkability and development.

Mid-Term TOD Strategies (2030-2040)

As initial TOD nodes mature and transit service expands, mid-term strategies should focus on strengthening connections between nodes and expanding the TOD approach to 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 bus rapid transit 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.
- 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 Strategies (2040-2050)

Long-term strategies should focus on systems transformation and creating truly transit-oriented communities 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.
- 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, significantly expanding the reach of the transit system without requiring personal vehicle ownership.

Special District Implementation Tools

Successfully implementing TOD at scale may require specialized governance and financing tools that transcend traditional municipal boundaries:

- Transit Benefits Districts: Create special assessment 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.

By implementing these strategies over time and adapting them to the unique characteristics of different communities throughout the five county region, transit-oriented development can become a powerful tool for reducing vehicle miles traveled while creating more vibrant, equitable, and sustainable communities.

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

7.5.5.1. GHG Emissions Reductions from Transportation & Mobile Sources

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.

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

Health 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 27 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 a business-as-usual case.

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

Segment	Reduction in SO2 (Tons)	Reduction in NOx (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**

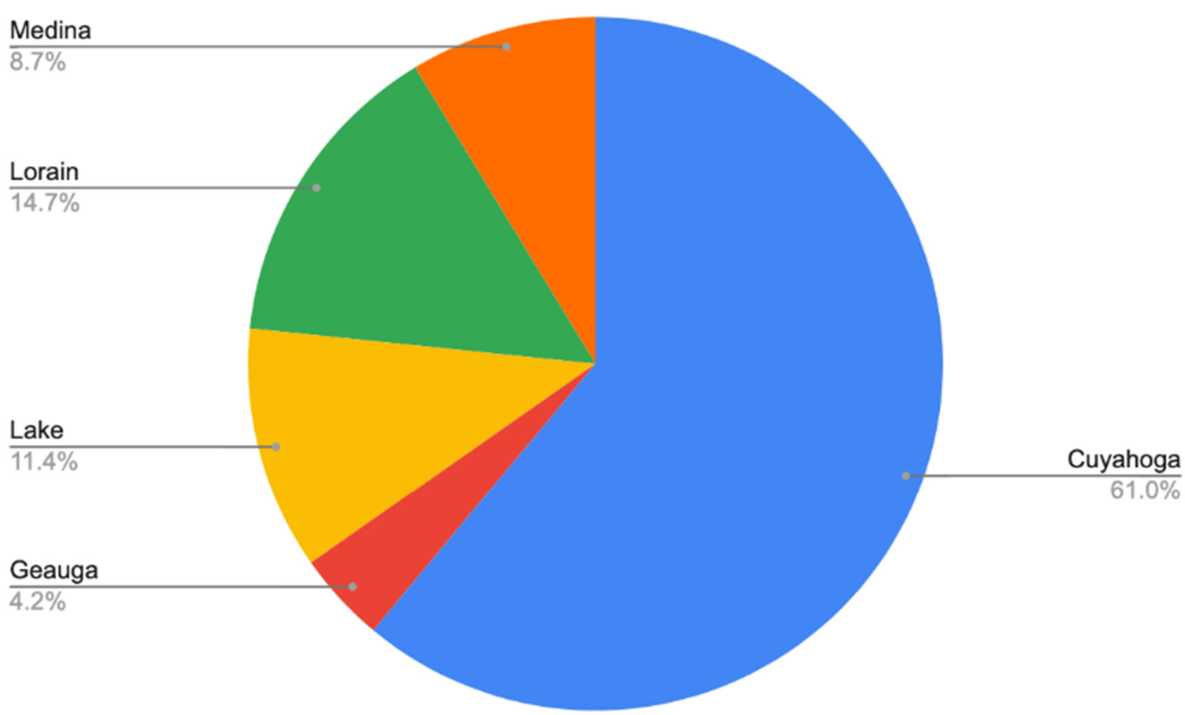
Noise Reduction Co-Benefits: EVs offer important co-benefits in the form of reduced traffic noise, particularly in urban and residential environments. Unlike internal combustion engine vehicles, EVs produce significantly less propulsion noise at lower speeds, where engine noise typically dominates over tire and wind noise. Studies have shown that EVs can reduce average pass-by noise by up to 4–5 decibels in city conditions compared to conventional vehicles.[270] 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.[271] The electrification of vehicle fleets—especially for transit, delivery, and municipal use—can help reduce these risks while also enhancing the livability and accessibility of public spaces.

7.6. Waste & Material Management Sector

7.6.1. MSA Context

Decarbonizing the Waste and Material Management Sector is important to accomplishing the net zero goals laid out in the Cleveland-Elyria MSA. The sector accounts for 9.5% of total GHGs in the MSA, with 5% coming from solid waste, 4% from HFCs (refrigerants), and 0.5% from water and wastewater. This section describes actionable strategies and policies to decarbonize Waste and Material Management.

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



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 the one in Geauga County, one in Lake County, four in Lorain County, and two in Medina County.

7.6.2. Challenges & Barriers to Decarbonization

The largest challenge in decarbonizing this sector is that the emissions are largely due to the biological processes associated with the breakdown of waste in a landfill or wastewater treatment facility.[272] These process emissions can only be avoided through waste reduction, so solutions have to capture the emissions produced through these processes. These gas capture systems can have high upfront capital costs. Similarly, the solutions to replace refrigerants with climate-friendly alternatives and create programs to properly dispose of HFC utilizing equipment at end-of-life take investments in training, education, and infrastructure.[273]

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 greenhouse gas emissions. Renewable-energy upgrades at the facility capture waste heat to spin turbines that generate 25% of the plant'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 consciously, but also implements sustainability measures that generate power.[274]

EDL is the owner and operator of the Lorain Renewable Natural Gas (RNG) facility. Working with the Republic Services Lorain County Landfill in Oberlin, Ohio, Lorain RNG converts 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 million MMBtu per year of pipeline-quality RNG. This saves the equivalent of about 5.5 million gallons of diesel p.a. 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.[275]

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 make immediate and sustained progress towards its near- and long-term GHG reduction targets. These measures largely correspond to the Refrigerants Capture and Solid Waste Diversion measures from the PCAP; however, this section builds upon that priority measures to provide 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 that come from Water and Wastewater. Emissions reduction measures in 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 resulting from industrial, commercial, agricultural, or community activities. Solid waste is not limited to wastes that are physically solid, it often takes the form of liquid, semi-solid, or contained gaseous material. The vast majority of human activities result in the production of some kind of solid waste.[276] 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).[277] Methods for decarbonization in the Solid Waste subsector 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 electrifying this equipment would reduce emissions by up to 60%, reduce noise, and directly improve air quality.[278] Additionally, some landfills have onsite propane heating that contributes to their emissions. Replacing them with an electric alternative could reduce their emissions by less than 1%.[279]

Alternative Fuels: Garbage collection fleets currently run on diesel. Switching to BEV or hydrogen FCVs would reduce 80-90% emissions from waste transport and would improve waste worker health.[280]

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.[281] This would minimize not only landfill dependence but also raw mineral extraction. Increasing recycling industries and encouraging novel recycling techniques that can utilize more landfilled items would reduce landfill emissions and manufacturing emissions because there would be less demand for raw materials.[282]

Currently, many landfills flare or vent their landfill gas, which wastes potential energy and emits methane. Instead, capturing landfill gas to produce renewable natural gas that can be sold to natural gas suppliers or used in waste-to-energy plants with a CCUS system can reduce landfill emissions by 35% - 90% and provide a renewable source of energy.[283] West Lorain landfill in Lorain County partnered with EDL energy to develop a renewable natural gas facility that became operational in November 2024.[284]

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%.[285] 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.[286] Community composting programs, local agreements with restaurants, and a system for promoting composting in public parts and at public events are strategies for reducing this waste stream as much as possible.

7.6.4.2. Water and Wastewater

Source: Rust Belt Riders

Water and wastewater treatment centers generate emissions from energy consumption, biological processes, and the incineration of waste. Southerly Wastewater Treatment Center and Lakewood Wastewater Treatment Center in Cuyahoga County are two examples of different strategies for utilizing 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%.[287] Lakewood Wastewater Treatment Center has anaerobic digesters that produce biogas, which they then burn to produce 100kW of electricity.[288] 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.[289] These shifts are the most important changes that other wastewater treatment centers should invest in for emissions reductions. Methods for decarbonizing this subsector 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. Optimizing pumps, motors, and other electro-mechanical devices by adjusting settings, investing in variable motor drivers, or adding automation to vary motor speeds based on demand will reduce overall power consumption.[290] Aeration is a critical step in wastewater treatment as it supports microbial decomposition, prevents odors, removes ammonia, and helps keep solids in suspension. Replacing traditional blowers with magnetic suspension blowers improves aeration efficiency and reduces energy use by 20-30%.[291] Heat is generated in the digestion and incineration processes, and utilizing this thermal energy with CHP systems after the digester or incinerator process can save 20% energy.[292]

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.[293]

Renewable Energy: Southerly, Lakewood, Medina County, and many other facilities in the region have infrastructure for capturing and combusting gas. Choosing 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. Heat is recovered and used to generate energy or used for heating.[294] They are less expensive to install than anaerobic digesters, produce less waste after combustion, and are better for human health.[295] Anaerobic digesters have microorganisms that break down organic material, and, through a fermentation process, produce biogas that is burned to generate 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.[296]

Alternative Fuels: Currently, natural gas is still used in fluidized bed incinerators to maintain an optimal combustion environment. Replacing natural gas with hydrogen or biogas for auxiliary fuel in fluidized incinerators would eliminate emissions from combusting natural gas.[297]

CCUS: Regardless of auxiliary fuel use, fluidized bed incinerators still are a combustion process breaking down organic matter and therefore emit CO_2. Adding a carbon adsorption bed to incinerators could capture up to 88% of CO2 emissions.[298]

7.6.4.3. HFCs (Refrigerants)

HFCs are refrigerants used in refrigeration and cooling. They are primarily used in air conditioning but also can be used in medical equipment. Cooling is highly energy intensive, accounting for 10% of all global electricity consumption. Additionally, HFCs are many times more potent than CO_2, with some having GWPs well over 1,000.[299] Methods for decarbonizing 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 reducing operating temperatures can reduce demand for HFCs and thus decrease emissions from their use. If all stationary air conditioning were replaced with the highest-efficiency refrigerants, an estimated 40% efficiency improvement would occur by 2030.[300] Preventing leaks 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.[301]

Process and Material Efficiency: Roughly 90% of GHGs from refrigerants are the result of leaking at the end of a refrigerant's life cycle. If machines that use refrigerants, like AC units and refrigerators, are brought to refrigerant management facilities at the end of their useful lifetimes to have their refrigerant destroyed, these emissions could be prevented. Just one year of proper handling of end of life refrigerants through destruction and recycling could save up to 2,990 $MMTCO_2e$.[302]

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

Decarbonizing the waste and material management sector reduces the amount of harmful co-pollutants in the region. From the EPA's COBRA tool, the reductions in these emissions are outlined in Table 30 for solid waste and water and wastewater treatment only since HFCs do not directly produce the harmful co-pollutants evaluated with the COBRA tool.

Table 30: Air Quality Co-Benefits from Waste & Material Management Sector Measures

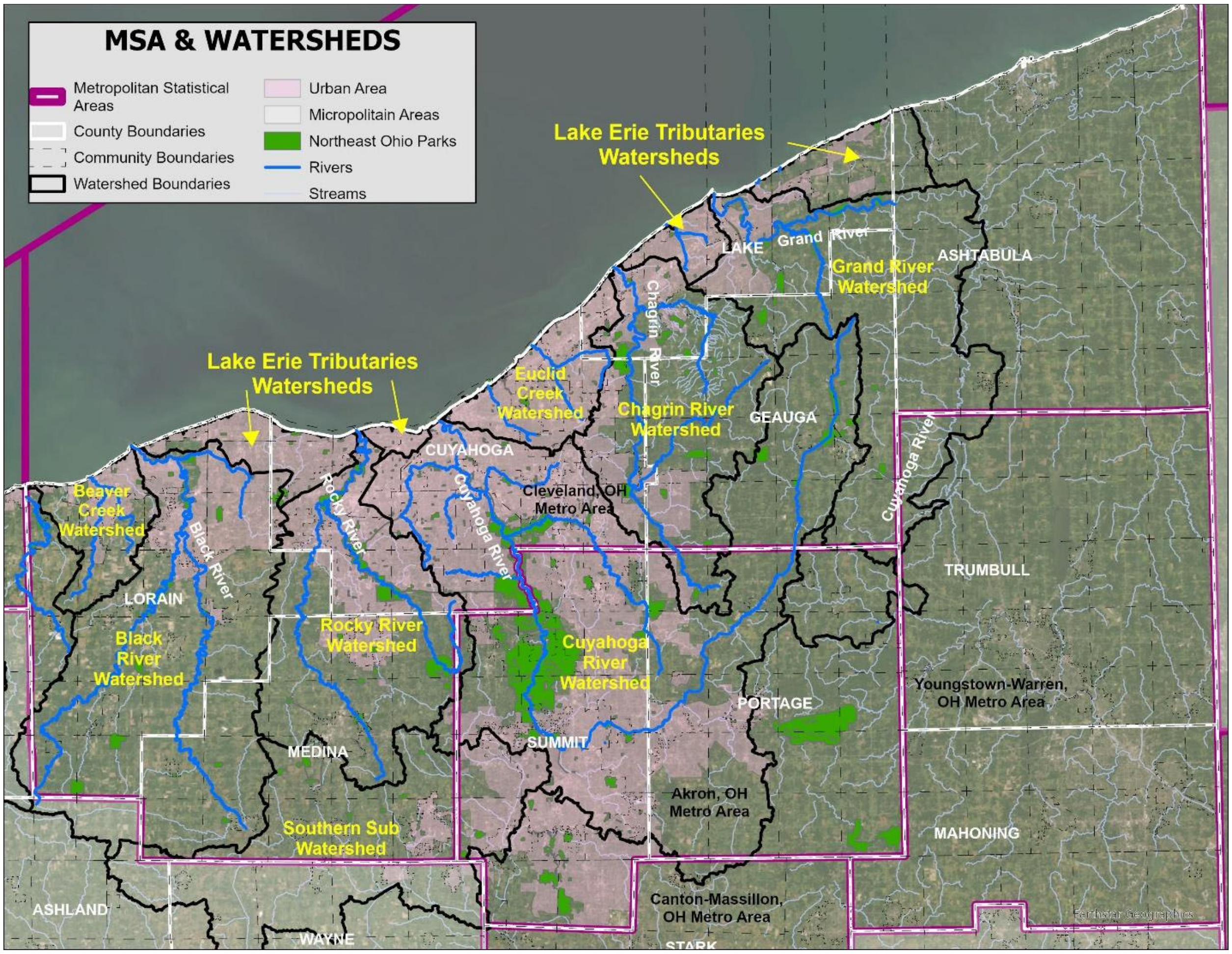
Subsector	Reduction in SO_2 (Tons)	Reduction in NO_x (Tons)	Reduction in VOCs (Tons)	Reduction in $PM_{2.5}$ (Tons)	Avoided Health Costs
Solid Waste	19.3	272	42.4	40.8	$17.4 million
Water & Wastewater	7.61	29.1	1.4	5.27	$2.1 million
Total	**27**	**301**	**44**	**46**	**$19.5 million**

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

7.7.1. MSA Context

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.

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



Cleveland's tree canopy has declined from 37% in 1950 to 17.9% today, while the five-county region averages 30%.[303] Strategic reforestation in underutilized areas would create carbon sinks while improving air quality, supporting wildlife habitats, and enhancing recreation. Restoring previously drained wetlands would also provide carbon storage, flood control, and water purification benefits. Though limited by available area, these projects regenerate biodiversity, improve water quality, and offer public education opportunities.

Zoning can incentivize carbon-negative land use by creating economic and regulatory advantages for landowners prioritizing sequestration. County planning commissions across the

MSA can develop model ordinances reflecting 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 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 one percent 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 the regional emissions, with agricultural emissions estimated at 0.8% of the 2022 total, and forests offsetting 4% of total emissions in 2022. The modest contribution to GHGs from this sector suggest that actions related to AFOLU 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 showing that well-designed stormwater or coastal wetlands can maintain mosquito densities no higher (and sometimes lower) than conventional detention basins.[304] 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.

Changing to conservation agriculture is hampered by risk management and cash flow realities. There need to be clear financial benefits to adopting no- or low-till agriculture or planting cover crops, and 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 out, and they are wary of mandates that might erode autonomy over land management decisions.

More than a hundred municipalities and numerous rural townships hold their own zoning authority, so aligning codes across the MSA is inherently difficult. Property-rights sensitivities, 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 ensuring that 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) are coordinating efforts to increase the City of Cleveland's tree canopy back to 30% by 2040, focusing 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 are re-establishing coastal wetlands.[305] Parma, working with the NEORSD, is buying out flood-prone homes on Pleasant Valley Road and restoring the natural floodplain to reduce flood risk and create new carbon sinks.[306] In 2024 the Lorain County Regional Planning Commission, with USDA support, completed a no-till suitability analysis that can guide soil carbon programs across agricultural lands.[307] Finally, the five county planning commissions are drafting 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 enable the Cleveland-Elyria MSA make immediate and sustained progress towards its GHG reduction targets. These measures largely correspond to the Nature Based Solutions and Agricultural Actions measures from the PCAP; however, this section builds upon that priority measures to provide 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; thus, the CCAP adds 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 filtering pollutants and regulating water flows. The City of Parma is already implementing this approach, as noted.

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/m²/year) in some constructed sites, often exceeding the rates observed in nearby natural wetlands.[308] 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 50 times lower than CO_2 sequestered. Because this is well above the GWP adjustment of 25:1, these ecosystems still provide a net climate benefit.[309] Factors like vegetation density, water depth, salinity, and soil iron content all influence methane flux, with saline and iron-rich systems generally suppressing 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.[310]

Wetlands also intersect with green infrastructure and energy strategies. Constructed wetlands used for wastewater or stormwater treatment can serve dual roles: capturing carbon while also producing 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. While fewer than 10% of U.S. wastewater treatment plants currently use biogas beneficially, the potential for expansion is high, especially in cities where biogas production can align with zero-waste and climate goals.[311] Constructed wetlands are generally less energy-intensive than traditional treatment systems and, with careful design, can match or exceed natural wetlands in carbon sequestration performance while also managing 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.[312] 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, integrating wetlands 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 requiring minimal maintenance once established.

7.7.4.2. Agricultural Practices

Agricultural decarbonization centers on increasing soil organic carbon (SOC), a key carbon sink that helps mitigate climate change by drawing CO_2 from the atmosphere and storing it in soils. Practices such as cover cropping, reduced tillage, and organic amendments are central to boosting SOC. Meta analyses show that cover cropping can increase near-surface SOC by an average of 15.5%, resulting in sequestration rates averaging 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 that improves soil structure, reduces erosion, and enhances water retention, while contributing to SOC accumulation over time.

Despite the promise of no-till (NT) farming, its effectiveness for long-term SOC sequestration is mixed. While NT improves soil aggregation and reduces erosion, which can reduce the risk of harmful algal blooms, studies show that it can increase SOC near the surface but often results in losses at deeper soil layers, especially if crop residue inputs decline. 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, blending trees into croplands, can further amplify benefits by storing carbon above- and belowground while improving biodiversity and stabilizing 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. However, given the limited agricultural lands in the Cleveland-Elyria MSA region, adoption of these practices should not be expected to provide significant decarbonization benefits.

7.7.4.3. Creating and Protecting Land Sinks

Expanding the Regional Tree Canopy: Once celebrated as the “Forest City,” Cleveland's tree canopy has declined to 17.9% (2017), losing 97 acres annually. Without intervention, cover will drop to 14% by 2040. Meeting the city's 30% canopy goal requires planting 28,000 trees yearly. Organizations like CTC, WRLC, and municipal partners facilitate regional expansion and merit continued investment.[313]

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 removing CO_2 from the atmosphere; man-made technologies are in development and being 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.[314] Mature trees reduce surface temperatures by 20-45°F on hot afternoons, saving millions in air conditioning costs - benefits that are least available to low-canopy communities most in need.[315] 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, with returns compounding as trees mature. Reversing canopy decline requires sustained maintenance funding and prioritizing heat-vulnerable, low-canopy neighborhoods where each tree provides outsized returns in cooling, health, carbon reduction, and stormwater management.[316]

Brownfield Restoration: The Cleveland-Elyria MSA contains numerous brownfields and underutilized properties that could be transformed into carbon sequestration assets. Special zoning categories should be developed for these sites, providing 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, ensuring these sites transition from environmental liabilities to climate assets.

The relative decarbonization benefits of transforming brownfields into green spaces versus solar installations can be quantified, though with notable differences in impact mechanisms and timescales. Solar development typically delivers greater immediate carbon reduction benefits, with utility-scale solar installations generating 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 including urban cooling effects that reduce energy consumption, stormwater management, and biodiversity enhancement.[317]

Green space and solar development do not have to be mutually exclusive. Solar arrays can provide 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 prioritized. 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: Communities across all typologies could implement soil carbon enhancement by using biochar. In urban areas, this could involve importing 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 providing 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, reducing landfill inputs while creating 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 ranging 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 significantly amplify climate action efforts. The following zoning approaches could be implemented across different community typologies to enhance carbon sequestration throughout the region.

Special zoning designations could be created to provide additional benefits for carbon-negative land uses throughout the region. These 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.[318] 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 context, these overlay zones could be particularly effective in rapidly developing areas of outer suburbs in Medina, Geauga, and Lorain counties, where new construction is actively reshaping the landscape. Municipalities could require carbon impact assessments as part of development review processes within these overlay zones, creating accountability for carbon outcomes while still allowing flexible approaches to meeting 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 seeking 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 directing growth to locations where it creates less carbon impact.

Agricultural conservation easements could be implemented more widely throughout the region's rural townships, particularly in areas identified as having high-quality soils capable of significant carbon sequestration. Local zoning codes could establish minimum lot size regulations that prevent fragmentation of carbon-rich land, maintaining 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 also mitigating flood risks and protecting water quality.

For communities along the region's rural-suburban fringe, these conservation zoning tools could help establish a clear edge to development, reducing pressure on agricultural lands while creating 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, moving beyond aesthetic considerations to prioritize ecological function.

Stormwater management zones that prioritize nature-based solutions could be established in flood-prone areas throughout the region, creating multi-functional spaces that capture carbon while managing 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 Cleveland, Lakewood, Cleveland Heights, and Euclid; and established towns, such as Elyria, Painesville, and Oberlin; these approaches could be particularly valuable in counteracting the urban heat island effect while creating more livable neighborhoods. Second-ring suburbs could incorporate these requirements into redevelopment of aging commercial corridors and office parks, transforming 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 implement these integrated approaches in developing town centers and commercial corridors, creating nodes of sustainable development that demonstrate how carbon capture can be woven into 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

The activities outlined above will result in some decarbonization benefits for the Cleveland-Elyria MSA.

Ecosystem Restoration: Wetland restoration could produce modest decarbonization. Restoration of an additional 500 acres by 2030 and 2500 acres by 2050 would result in 2,000 and 10,000 $MTCO_2e$, respectively, using an emissions factor of 4 $MTCO_2e$ per acre, per year. This would offset less than 0.01% of regional 2022 emissions. Prairie and other ecosystem restoration of agricultural lands or on brownfields would result in more effective emissions offsets. Assuming the restoration results in a 1 $MTCO_2e$ per acre, per year change in the emissions factor, targeting 5,000 acres of newly restored land would lead to 25,000 acres by 2030 and 100,000 acres by 2050, with a net reduction in emissions of 25,000 and 100,000 $MTCO_2e$ for 2030 and 2050 respectively. This would constitute 0.3% of 2022 regional emissions.

Agricultural Practices: The recent 2022 GHG inventory estimates the baseline situation 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.

The cumulative emissions savings from the AFOLU sector could be as high as 253,647 $MTCO_2e$ by 2050. This would be due to annual reductions of 10,000 $MTCO_2e$ from wetland restoration, 100,000 $MTCO_2e$ from ecosystem restoration (reforestation and prairie restoration), 121,154 $MTCO_2e$ from additional regional reforestation associated with adding conservation lands, 16,243 $MTCO_2e$ through biochar amendments to agricultural soils, and 6,250 $MTCO_2e$ from adoption of conservation agriculture.

7.7.5.2. Co-Benefits from AFOLU Measures

Across the Cleveland-Elyria MSA, existing urban forests perform heavy environmental work. Every year the canopy intercepts roughly 10-20% of rainfall, avoiding sewer overflow treatment. The canopy in urban areas also provides important cooling benefits in cities where urban heat island effects are the strongest. These services in addition to air pollution removal and property value gains are valued at more than $28 million annually for the City of Cleveland alone, values that will erode in step with canopy loss.

Beyond climate mitigation, wetlands offer a suite of additional ecosystem services. They act as natural sponges, reducing flood peaks by storing and slowly releasing stormwater, an especially critical function in the face of increasingly severe weather.[319] Riparian and downstream wetlands improve watershed resilience by sustaining baseflows during drought and intercepting nutrient-rich runoff from agriculture and urban areas. These systems filter nitrogen and phosphorus through microbial uptake and denitrification, preventing harmful algal blooms and improving aquatic habitat quality. 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, 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 AFLOU sector scale with land surface area, thus the greatest regional decarbonization benefits will be generated by focusing actions on areas with more land (primarily rural areas with a low population density). The concentration of LIDAC communities is in the urban areas, thus it remains a challenge to perform enough AFLOU decarbonization activities in urban areas so that LIDAC communities experience the co-benefits of the AFLOU decarbonization actions. However, there are substantial cooling and flood reduction benefits from urban trees, so concentrating on urban tree planting will have strong positive co-benefits in urban areas while the decarbonization benefits will be lower than rural areas where many more trees can be grown per acre. LIDAC communities are more likely to have more impervious pavement, resulting in more urban heat effects and more flooding potential. So the addition of trees and green infrastructure will help mitigate the heat and flooding effects on these communities.

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 achieving reductions in GHG emissions, significant reductions will also be achieved 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 sulfur SO_2, NO_x, VOCs, and $PM_{2.5}$. Reducing these emissions will improve air quality and reduce the negative impacts on human health.

Table 31 presents the combined reductions in co-pollutants across emissions reduction measures, while Tables 32-36 provide estimates from individual sectors.

Table 31: Combined Reductions in Co-Pollutants from All Measures[320]

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	1,515.45	9,266.61	2,542.91	2,962.80
Geauga	127.54	963.30	433.59	518.40
Lake	1,662.22	1,937.01	559.54	554.78
Lorain	310.77	2,064.79	804.04	908.83
Medina	196.25	1,575.69	625.85	646.78
Total	**3,765.92**	**12,729.20**	**4,871.33**	**5,578.68**

Table 32: Reductions in Co-Pollutant from Electricity by County

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	1,148.02	624.92	11.59	74.3
Geauga	84.48	45.99	0.85	5.47
Lake	192.14	104.59	1.94	12.43
Lorain	231.63	126.09	2.34	14.99
Medina	139.39	75.87	1.41	9.02
Total	**1,795.65**	**977.46**	**18.12**	**116.21**

Table 33: Reductions in Co-Pollutant from Buildings by County

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	38.49	2,683.74	1,043.31	1755.77
Geauga	10.48	167.39	323.36	369.05
Lake	12.04	459.72	386.71	515.55
Lorain	17.48	555.86	557.06	689.26
Medina	13.48	333.84	424.16	503.94
Total	**91.97**	**4,197.54**	**2,734.61**	**3,833.57**

Table 34: Reductions in Co-Pollutant from Industry by County

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	241.72	1,940.32	1,323.08	1,062.64
Geauga	26.05	449.48	97.04	138.64
Lake	1,440.17	549.59	137.10	12.44
Lorain	40.58	411.65	204.77	187.63
Medina	29.48	525.95	174.01	122.65
Total	**1,778.00**	**3,877.00**	**1,936.00**	**1,524.00**

Table 35: Total Reductions in Co-Pollutant from Transportation by County

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	42.48	1,956.84	80.33	34.14
Geauga	3.43	157.82	6.48	2.75
Lake	9.54	439.34	18.04	7.66
Lorain	10.32	475.49	19.52	8.30
Medina	7.53	346.72	14.23	6.05
Total	**73.30**	**3,376.20**	**138.60**	**58.90**

Table 36: Total Reductions in Co-Pollutant from Waste and Material Management in Cleveland-Elyria MSA

County	SO_2 reduced	NO_x reduced	VOCs reduced	$PM_{2.5}$ reduced
Cuyahoga	44.74	2,060.79	84.60	35.95
Geauga	3.10	142.62	5.86	2.49
Lake	8.33	383.77	15.75	6.70
Lorain	10.76	495.70	20.35	8.65
Medina	6.37	293.31	12.04	5.12
Total	**27.0**	**301.0**	**44.0**	**46.0**

Table 37, below, quantifies the public health benefits of 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. 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 annual health benefits. Table 38 breaks down reductions in co-pollutants from large emitters across the MSA.

Table 37: Total Air Quality-Related Health Benefits from 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**

Table 38: Detailed Reductions in Co-Pollutants from Large Emitters by County [321]

County	City	LIDAC	Company	SO_2 Reduced	NO_x Reduce	VOCs Reduced	$PM_{2.5}$ Reduced
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**

By decarbonizing industrial processes and operations harmful emissions can be reduced, directly improving public health, electrification reduces noise and vibration making work environments safer, improvements in water usage efficiency decreases the amount of industrial water waste, and new industrial support will create new job opportunities in the region.

8.2. Additional Benefits

Nearly all of the measures described in this report have additional benefits beyond reductions in GHG emissions. Below we describe the benefits that exist across sectors. Broadly, 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 39, below provide an outline of the technologies and strategies identified and proposed throughout the CRDF organized by sector and describe their additional benefits and disbenefits.

Table 39: Benefits and Disbenefits of Measures for LIDAC by Sector

Electricity Sector		
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.
Commercial & Residential Energy		
Measure Name / Description	**Metrics**	**Benefits / Disbenefits**
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.	Reduced cooling loads, better public health, and ecosystem restoration in urban areas.

	Decrease in ambient summer temperatures within urban core	
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
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, create 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	Active transportation confers health benefits; Mobility options for people below the driving age and for those without cars
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	100 street trees, Change in % forest canopy	Shading/cooling and canopy interception of rainfall; Less energy needed for cooling, less storm water in yard, but more tree maintenance cost

and provide numerous co-benefits	using national Tree Canopy Cover data	

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

There are both measure specific and cross-sector disbenefits to implementation that must be carefully considered and anticipated. Here we provide a general overview of potential disbenefits across a range of measures.

Cost Prohibitive: Measures recommended will require substantial investments to implement, as well as major infrastructural improvements. The costs involved may prove prohibitive creating delays to implementation and serve as a barrier to implementation. Disbenefits can also involve long-term costs for maintaining interventions.

Workforce Displacement: Job losses, particularly for lower-skilled workers, due to the adoption of new technologies requiring 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 infrastructural 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 valuation can result in increased property taxes and could potentially result in displacing 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. Ensuring the quality of installation and having trained installers and inspectors are necessary to prevent this. The lack of quality installers and the difficulty of determining the qualifications of installers are potential barriers, but ensuring adequate inspection and training and or certification of installers can reduce this barrier to adoption.[322]

Industry Uncertainty: Consumers may face challenges navigating market uncertainty as lots of new companies emerge that may face smaller and uncertain profit margins and consequently experience higher rates of failure. If the company and or installer changes hands, goes bankrupt, or out of business this may create long-term disbenefit for consumers when it comes to post-purchase experiences.[323]

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 and /or create safety hazards with increased frequency of severe storms, representing a significant disadvantage for residents.

Negative Impact on Future Development: A potential disbenefit associated with increasing tree canopy in urban neighborhoods, for example with efforts to regreen vacant parcels, could be the delay or prevention of future transit-oriented development by reducing the density needed for frequent public transit. There is also a disbenefit when resources are spent on planting trees in a neighborhood that are later cut down for new development, indicating 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.

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).[324] 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.

Generally speaking, LIDAC areas 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. Conducting a LIDAC benefits analysis is a critical step in paving the way to outcomes that can spur improved sustainability and greater resilience for residents of LIDAC communities.

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

Drawing upon analysis used in the *Cleveland-Elyria MSA Priority Climate Action Plan* identified, 253 2010 Census tracts were identified as LIDAC Census tracts, 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. LIDAC communities identified are the same as those identified in the PCAP.

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 listed as burdened for that indicator.

For a list of all Census tracts identified as LIDACs (based upon the 2010 Census) in the Cleveland-Elyria MSA, please refer to the Technical Appendix.

Roughly 43.4% of all census tracts within the Cleveland-Elyria MSA are LIDAC tracts. These tracts are primarily concentrated in Cuyahoga County (88%), with most of these located within the City of Cleveland (66% of MSA total). Within the City of Cleveland the neighborhoods with the highest absolute number of LIDAC communities include: Glenville, Broadview-Slavic Village, Hough, and Mount Pleasant, though there are LIDACs in nearly every statistical planning area (SPA).[325] In 24 neighborhoods nearly every census tract, at least 80% of the census tracts in that neighborhood, qualified as a LIDAC. Other municipalities with a significant absolute number of LIDAC tracts include Lorain, Euclid, East Cleveland, and Elyria.[326] [327] Additional cities with a significant proportion of LIDAC tracts include Maple Heights, Garfield Heights, Painesville, and Warrensville Heights.

Table 40 provides a visualization of the distribution of LIDAC census tracts across communities in the five-county MSA illustrating the concentration and uneven dispersion of LIDAC communities in the region. Tables 41 and 42, in turn, identify the neighborhoods/SPAs and cities with the highest concentration of LIDACs throughout the MSA.

Table 40: 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%**

Figure 39: LIDAC Census Tracts in Cleveland-Elyria MSA

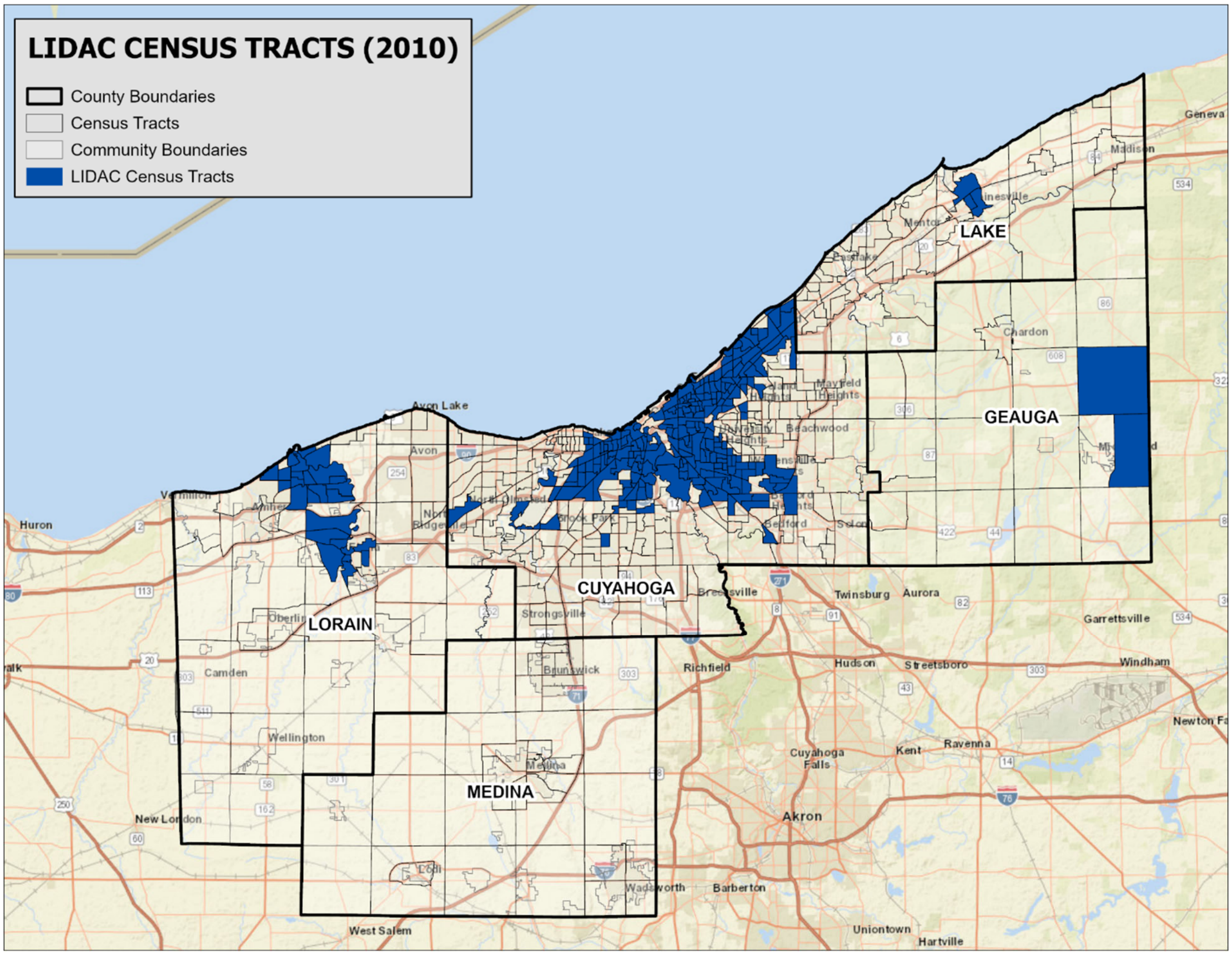


Table 41: Cleveland Neighborhoods with the Highest Concentrations of Disadvantage

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 42: Cities Outside of Cleveland with Highest Concentrations of LIDACs [328]

City	Total LIDAC Census Tracts	Total Census Tracts in City	LIDACs as % of Total Tracts
Lorain	17	19	95%
Euclid	12	16	75%
East Cleveland	11	11	100%
Elyria	9	20	45%
Garfield Heights	6	10	60%
Warrensville Heights	5	5	100%
Maple Heights	4	7	57%
Painesville	3	5	60%

When identifying LIDACs, one should note that while there are some LIDACs in every county with the exception of Medina County, the overarching pattern of their location indicates a high degree of spatial concentration of disadvantage. LIDAC communities often are disproportionately composed of populations that are particularly vulnerable to climate hazards.

Table 43 displays the 10 Census tracts that in the MSA that exceed at least seven CEJST categories, while Table 44 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, illustrating the concentration of burden within the region.

Table 43: 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 44: 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 (Euclid, East Cleveland, Cleveland Heights, Garfield Heights, Lakewood, and Warrensville Heights) face severe burdens from economic and environmental disadvantages.

LIDAC communities have salient socioeconomic and racial demographic characteristics that differentiate them from the region more broadly. As noted in the PCAP "while nearly one-third (31.2%) of Northeast Ohio residents identify as people of color, they are the majority (51.5%) in

LIDACs. While 28.7% of all residents qualify as low income, that share reaches 44.3% in LIDAC tracts. Moreover, the unemployment rate in LIDACs (4.8%) is 50% higher than in the region (3.3%).” This can be further elaborated by considering the demographic composition of places where LIDAC census tracts are heavily concentrated.

A general overview of the demographic characteristics of communities that vary in terms of the number and concentration of LIDAC tracts across the region is provided in a table in the appendix. Communities across the region in the table are classified in terms of high (30 percent or higher), medium (29-10%), and low concentrations (less than 10%) of LIDAC tracts. A city that encompasses a total of three census tracts, with one designated as LIDAC would be considered to have a relatively high concentration of LIDAC census tracts. Communities with high concentration of LIDAC census tracts tend to have comparatively low rates of homeownership and lower levels of educational attainment.

9.2. Meaningful LIDAC Engagement

Community engagement in preparation for this CCAP with LIDAC communities entailed multiple concurrent processes of collection of community input. The City of Cleveland conducted several rounds of engagement within the city boundaries targeting communities with high concentrations of LIDACS. NOACA commissioned a consulting firm, Joel Ratner Community Consultants, to gather community input in Lake, Geauga, Medina, and Lorain counties. Lastly, a small subset of individual municipalities that contain LIDACs within Cuyahoga County engaged and collected feedback from their residents. Below each of the forums of engagement are described.

9.2.1. City of Cleveland LIDAC Engagement

A central goal orienting the community engagement work conducted by the Cleveland’ MOS was to include groups and neighborhoods that were underrepresented during the past PCAP engagement. Feedback and insight from community members was collected from multiple sources including community roundtable discussions, educational workshops, and a survey. Efforts to communicate the findings of the community workshops entailed presentations to the Climate Advisory Council & Steering Committee (meetings held in July and October 2024) and outlined in the 2025 CAP update.

Cleveland Community Climate Action Survey: The City collected survey data was from 368 respondents from July 22-August 16, 2024. The survey was available in English and Spanish. The survey aimed to gather insight about the central goals and objectives the City should prioritize in its CAP update. Respondents were asked to evaluate possible climate actions. Key findings from the survey include participants expressed 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
(5) Litter clean up and better waste management practices

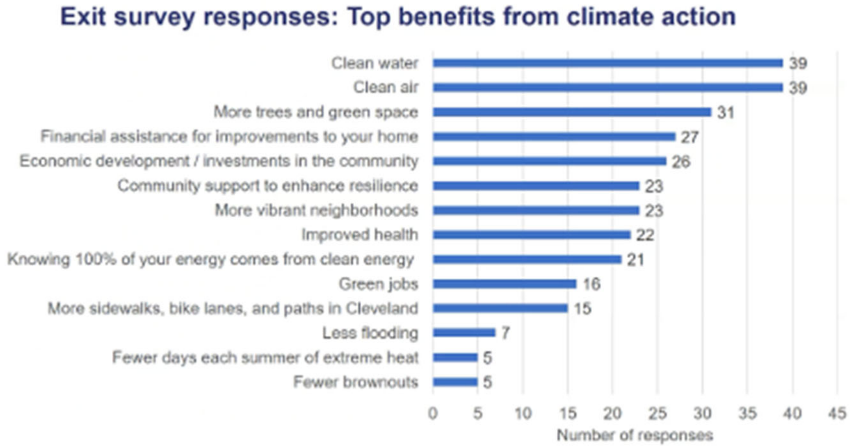
While a helpful tool, a key limitation of the survey was that respondents skewed middle-class and advantaged, thus not representative of the city's demographics or of LIDAC communities more broadly. More specifically, the respondents were 73% white, 76% with a bachelor's degree or higher, and 32% with incomes $100,000 or over. Nonetheless feedback gleaned from implementing the survey and responses helped to guide the organization and to direct efforts to ensure greater representation with the in-person community roundtables.

Community Roundtables: The City of Cleveland commissioned Elizabeth Schuster from Sustainable Economies Consulting and Bianca Butts from Free by Design to conduct six community roundtables targeting nine neighborhoods with the City of Cleveland during August and September 2024[329]. Each roundtable was organized in coordination with a community-based organization, which served as a partner and co-host. In some instances, community organizations were provided a stipend ($3000) for their efforts to recruit participants and spread the word about the roundtables. Extending (limited) financial resources to these hyper local organizations was seen as a way to garner good faith and build on established trust. Roughly, at minimum, a two week period was extended to promote the roundtable meeting to prospective participants, with flyers and other materials distributed through a range of platforms.

Neighborhoods were selected with consideration of a number of factors, including PCAP data on the LIDACs that stood to benefit the most from priority climate actions. Sites were selected with the goal that they would be accessible (e.g. on transit line), safe, and familiar to 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 with more than 50% having annual incomes of less than $50,000. Efforts were taken to ensure accessibility for Spanish speakers, including a translator in the roundtable that targeted neighborhoods with high concentrations of Latinos. More detailed information and summaries of the findings from the community roundtables is available online on the City of Cleveland Office of Sustainability and Climate Justice website.[330] Participants were provided with a catered meal at most of the events and in some instances participants were provided gift cards.

A poster displaying a graph of the sources of emissions and images that reveal poor air quality and low visibility over Lake Erie were made visible for participants prior to and during the workshops. Each roundtable began with a general discussion of the impact of climate change on neighborhoods and a discussion of residents' aspirations for their neighborhood. This discussion was followed by a brief presentation, usually conducted by MOS staff. Staff members used the visual aid to illustrate the impacts that climate change is already having on the City of Cleveland, 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 sectors they considered the most important and then engaged in a breakout session that focused on one of the top sectors that ranked the highest. The discussions during the breakout sessions focused on the barriers to implementation, as well as potential solutions. Additionally, participants were asked about blind spots in the City's climate planning process. After the breakout sessions, participants c an exit survey.

Figure 40: What Are The Top Benefits of Climate Action?



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, the most frequent replies were the impacts of storms (22), flooding (12), and the impact on plants and trees (11) coming in third. Similarly, the exit surveys revealed what the participants saw as the potential benefits to efforts taken to address climate change. The top ranked benefits include; 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 41: What Are Climate Change Impacts that Worry You the Most?

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 strategies and measures outlined in the CCAP were developed.

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 reducing waste, to building retrofits and improvements to energy efficiency, to training youth to enter green jobs, and facilitating greater awareness and climate literacy, schools were discussed in nearly every roundtable and viewed as sites with great potential for impact. The desire for public education was further corroborated in the analysis of 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?” with the most salient reply being to ensure that “communities are informed and educated on issues.”

Educational Workshops: In order to take a more active and participatory approach and increase awareness of the climate planning process, the City of Cleveland also hosted four educational workshops from September to October 2024. The educational workshops varied in their format and content and aimed at soliciting insight about the CAP in a less structured way. They 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 LIDAC communities unrepresented in previous work, NOACA contracted with JRCP, the firm that was responsible for organizing and orchestrating community workshops across Lorain, Medina, Lake, and Geauga counties. The sessions took place at various locales, including an assisted living facility, an elementary school, and community center.

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

Of the eight categories offered, (1) Air Quality Concerns, (2) Drought, (3) Flooding, (4) Wildfire Smoke, (5) Severe Thunderstorms, (6) Flooding, (7) Extreme heat, (8) Severe Winter Weather, and (9) Water Pollution. The following were most frequently selected: *<insert findings>.* Concerns about air quality were frequently discussed in terms of the adverse health impact on children, grandchildren and other family members who suffered from asthma and allergies.

Several priorities were raised across sessions including the impact of policies on jobs, air quality and health. For example, when discussing the benefits of decarbonization including the closing of a Painesville coal powered plant, several participants in different sessions expressed concerns about workers who might be displaced. Simultaneously people noted that there were deleterious conditions and impacts on community health as a consequence of the operation of such facilities, they expressed a heightened awareness of the impact of pollutants on respiratory conditions, causing upticks in asthma, for example. Improvements to public transportation were also raised as a priority by residents in the Lorain session. Concerns about transportation were thought to extend to companies and employers who were seen as playing a role in facilitating worker's access to reliable transportation.

For these communities, key benefits that would make them amenable to plan 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, and 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 provides critical insights from Cleveland Heights, a community within the region that 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 which will work with selected communities and 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 central 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 from October 2023-October 2024.[331]

Cleveland Heights' engagement indicated several overlapping concerns and impacts of climate on disadvantaged and vulnerable populations. The impact of climate on health, both mental and physical, was a shared concern, particularly as poor air quality, extreme heat, and severe storms serve as climate hazards. Additionally, residents prioritized efforts to provide assistance for low-income households to pursue home improvements that enhance resilience, including for renters. The sessions also spotlight areas that differ and may reflect the demographics of the community. For example, business owners were seen as likely to be adversely impacted by transit disruptions resulting from severe storms, creating conditions that make it difficult for workers who are transit dependent to get to work.

9.2.4. Integrating Feedback from LIDACs into CCAP Development

Drawing on feedback and input communicated during these engagements, the CDRF team developed a synthesized list of LIDAC priorities and concerns, outlined in Table 45. The team then used this feedback inform the team the list of emissions reduction measures in this CCAP.

Table 45: 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 gov. 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

LIDAC communities stand to benefit both directly and indirectly from measures that reduce GHG emissions implemented across sectors. Targeted investments in LIDACs will help to accelerate the impact of these measures. Table 46 outlines the specific measures that are most likely to produce benefits to LIDAC communities. We define the impacts broadly in four categories: health, economic, social, and environmental.

Table 46: Summary of Benefits of Emissions Reduction Measures for LIDACs

Measure	HEATH: 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 Fai		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		
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

Beyond the GHG reductions the proposed measures have co-benefits. A key co-benefit that will result in improved public health are the reductions to co-pollutants. Across Cuyahoga, Lake, and Lorain Counties these reductions are projected to take place primarily in LIDAC census tracts. As Table 47 illustrates, a significant proportion of co-pollutant reductions will occur and be experienced by LIDACs.

Table 47: Air Quality Co-Benefits from Industry Measures in LIDACs & Non-LIDACs

County	Location of Facility	SO_2 Reduced	NO_x Reduced	VOCs Reduced	$PM_{2.5}$ Reduced
Cuyahoga County	LIDAC	63.8	35.66	16.6	3.93
	Non-LIDAC	45.93	37	4.83	2.05
Lake County	LIDAC	0.33	2.09	4.67	0.69
	Non-LIDAC	0	0	0	0
Lorain County	LIDAC	54.11	110.84	14.4	12
	Non-LIDAC	0	0	0	0
Medina County	LIDAC	0	0	0	0
	Non-LIDAC	0.01	12.63	4.79	0.45
MSA Total	LIDAC %	99%	86%	82%	94%
	Non-LIDAC %	1%	14%	18%	6%

9.3.2. Disbenefits of Emissions Reduction Measures on LIDACs

Just as with the entire region there are both measure specific and cross-sector co-benefits and disbenefits to implementation that will accrue to LIDACs that must be carefully considered and anticipated.

In the Benefit Analysis section a detailed overview is provided of the disbenefits to the region of the measures outlined in the CRDF. Many of the outlined disbenefits are the same for LIDACs. Nonetheless, below we highlight the specific disbenefits that may have an outsized impact on LIDAC communities.

(1) **Cost-Prohibitive**. Measures recommended will require substantial investments to implement and maintain. For communities with high concentrations of LIDACS this will pose a challenge as the need may far outweigh the available resources, constraining local governments' ability to invest to the extent 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 and /or create safety hazards with increased frequency of severe storms, representing 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.** A potential disbenefit associated with increasing tree canopy in urban neighborhoods, for example with efforts to regreen vacant parcels, could be the delay or prevention of future transit-oriented development by reducing the density needed for frequent public transit. There is also a disbenefit if resources are spent on planting trees in a neighborhood that are later cut down for new development, indicating a less than optimal use of critical resources.

(5) **Workforce Displacement.** Job losses, particularly for lower-skilled workers, due to the adoption of new technologies requiring 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.

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 is created by 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.[332]

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 the public health, morals, safety, or general welfare of the community.[333]

Police power is especially well established in enacting and enforcing land use laws. Local governments have both police power and delegated authority from the legislature to establish climate changes policies and regulations to reduce GHGs in general plans, CAPs, zoning, 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.[334]

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.[335] Local jurisdictions also act with the authority to tax, issue bonds, and impose fees, charges, and rates.[336] This authority is derived from and limited by the Ohio Constitution and statute, including requiring voter approval for taxes and bonds.

The 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 regard to authority. It was designed to be comprehensive but not exhaustive given the complexity of some of the laws involved and the lack of activities in certain areas such as natural climate solutions. Additional work would be needed in this area to understand the opportunities and challenges presented by local policies.[337]

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.[338] When local law conflicts with general law, 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. Tailpipe emissions standards are set by the federal government, and state and local governments cannot enforce alternative standards, though California is permitted to apply for waivers from U.S. EPA under §208 of the Clean Air Act Amendments (CAAA) of 1970. Local limits on emissions from interstate commerce, aircraft, or rail in Ohio are preempted by state law 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 be in 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.[339] 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 of which electrification of municipal fleets and public transportation is a key tenet.

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), but 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 are that 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 in order 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 under, 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 that targets businesses whose focus is decarbonization, energy efficiency, waste reduction and re-use, green building materials, tree nurseries, and similar materials, technologies or strategies, can be powerful engines for growth for the region and its communities. For example, Ohio offers an incentive program to encourage the installation of solar power. Such incentives include Solar Renewable Energy Certificates (SRECs) which allows 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. These incentives demonstrate how governments can use industrial development policy to foster decarbonize.[340]

Decarbonization efforts pertaining 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 would have to 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, with the exception of the City of Oberlin in Lorain County, also do not have CAPs. If more municipal and county governments acted as first movers to advance climate action, there may be a greater appetite within the state legislature to enact changes that would make those efforts more successful.

10.3. Opportunities to Expand Local Authority

There exist a number of 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 to pilot demand response programs for residential buildings, and advocate for State of Ohio policies that enable IOUs to actively participate in and scale such programs, will meaningfully contribute to decarbonization, for example.

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;
- Rolling out smart meters and access to real-time energy data through IOU rate cases;
- Promoting the development and deployment of Virtual Power Plants (VPPs) to aggregate distributed energy resources for grid reliability, renewable integration, and emission reduction before both the PUCO and the legislature;
- Encouraging the 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 equitably 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 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 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 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 implementing each measure, consult the *CCAP Implementation Playbook* and the Technical Appendices.

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, or their future remain uncertain.

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 combining or “stacking” multiple financing mechanisms together 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 potential utilize to pay for CCAP measures, consult the Technical Appendix, which outlines funding opportunities for each measure and details whether entities within the region have already secured implementation funds.

12. Workforce Planning Analysis

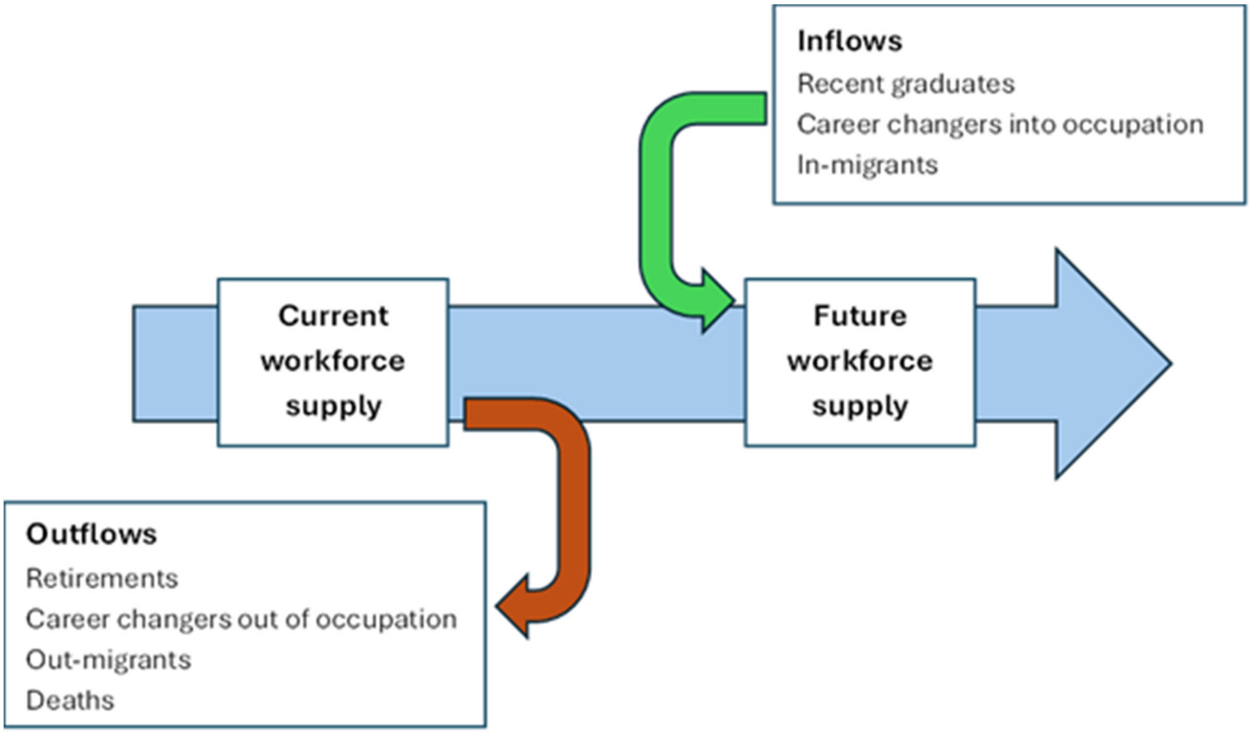
A skilled and adaptable workforce is critical to realizing the region's GHG reduction goals. This section outlines potential workforce shortages that could impede implementation of the priority measures identified in this framework. For potential workforce shortages, strategies are proposed to address these challenges, including potential partners who can help address them. 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.[341]

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.[342] 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. Occupations suggested by the chatbot were validated against the U.S. Department of Labor's O*NET occupational database.[343] 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. A straightforward approach compared to more complex statistical methods, stock-and-flow models are widely used by both U.S. federal agencies and international bodies such as the World Health Organization to project workforce supply by occupation.[344] A conceptual version of the stock-and-flow model used to project workforce supply is shown below.

Figure 41: Stock-and-Flow Model for Workforce Supply Projections



Source: Adapted from Crettenden et al. [345]

Workforce supply for an occupation depends on the number of workers currently employed in the region, individuals moving into or out of a region, recent graduates of local educational programs, career changers entering or leaving an occupation, and those exiting the workforce entirely, such as through retirement.

Data on current occupational employment by SOC code for the Cleveland-Elyria MSA were obtained from the Bureau of Labor Statistics (BLS) via its Occupational Employment and Wage Statistics (OEWS) program.[346] In addition to using data from the American Community Survey (ACS), estimates of workforce inflows and outflows were developed using the U.S. Census Bureau's Current Population Survey (CPS) and the U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS).[347] Labor supply estimates were based on the five most recent years of available data.

Projected workforce demand and expected workforce exits by occupation by occupation in the Cleveland-Elyria MSA were obtained from the Ohio Department of Jobs and Family Service (ODJFS) through its Occupational Employment Projections.[348] These projections are based on BLS data, localized to reflect anticipated occupational demand in each of Ohio's MSAs.[349] BLS-based employment projections represent the number of jobs needed to support expected future economic activity.[350]

For each occupation required to implement GHG reduction priority measures, projected workforce supply was subtracted from projected workforce demand to assess the risk of shortage in the Cleveland-Elyria MSA. If projected demand exceeded supply, the occupation was flagged as having a potential workforce shortage. For such occupations, solutions will need to be identified to address the regional workforce shortage.

Table 48 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, with both the absolute and percentage difference shown. Occupations where demand exceeds supply are flagged as 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 48: 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
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. Addressing Workforce Shortages for CCAP Measure Implementation

Once workforce shortages are identified, the next step is to consider targeted strategies to address them. 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, drawing on a recent climate sector workforce landscape analysis commissioned by the Cleveland Foundation, which provides a timely foundation for building a broadly shared regional climate workforce development strategy.

12.2.1. Align 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. Create 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.

<u>Practical steps</u>:

- 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. Engage 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 for creating placement opportunities and aligning training to real demand.

<u>Practical steps</u>:

- 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. Integrate 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.

<u>Practical steps</u>:

- 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. Pilot and Scale 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.

Practical steps:

- 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 risks falling short of meeting 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.

13. Conclusion

Implementing this CCAP and achieving 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 illustrated, climate change presents a clear and present threat to the Cleveland-Elyria MSA, and people across the region are already feeling 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. We are feeling its effects now, and these impacts will only compound if we do not act decisively to address this challenge.

Chapters 8 and 9 also demonstrate that climate action represents an unprecedented opportunity to envision a new future in which the Cleveland-Elyria MSA is once again a dynamic, growing, 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 Implementation Playbook outline strategies that are accessible for all communities, no matter where they are along that path. Community leaders are able to choose the measures that best address their unique needs and respond to their specific conditions. Nevertheless, the CCAP has identified six priorities for the MSA that will put the region at the forefront of climate action and make it competitive not just throughout the Great Lakes but across the country. These include:

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

Achieving these actions 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. If we succeed in implementing this CCAP, we will go a long way towards making the region healthier, wealthier, and safer, both today and for future generations. The arc of the moral universe may bend towards justice, but it doesn't bend by itself. It's up to the people of this region to decide where and how quickly to bend that arc.

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