Understanding

the regulatory environment of climate change and the

impact

of community design on greenhouse gas emissions.

ATLANTA REGIONAL COMMISSION

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Preface

Actions and opinions on climate change are evolving quickly. The Supreme Court ruled, in 2007, that the Environmental Protection Agency (EPA) is mandated under the Clean Air Act to regulate greenhouse gas emissions[1]. The Office of the President has developed a climate action plan that strives to reduce greenhouse gas emissions and prepare America for the impacts of a changing climate.[2]

A survey conducted in October 2013 by Pew Research found that 67% of Americans believe there is evidence the planet is warming with a plurality (44%) believing the causes are mostly man-made.[3] Among scientific circles, the debate over climate change is less evenly split. As of January 2013, 97% of published climate papers take the position that climate change is happening and that humans are the cause.[4] Scientists have overwhelmingly come to the consensus that people are impacting the world we live in by changing the chemical structure of the atmosphere.

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Whether or not Congress enacts federal climate change action based on the advice of the scientific community remains to be seen. While Congress debates comprehensive action, other branches of the federal government, states, regions and cities across the United States have begun to investigate their greenhouse gas emissions and are devising plans to reduce their contribution to climate change. Regions that take steps to understand their greenhouse gas emissions, and provide their communities with policy options, are taking a seat at the climate change national table. These communities will help to inform federal policy on the issue in the future.

This report is designed to serve three primary goals. First, it will briefly explain some background information on climate change. Second, this report will outline some of the local, regional and federal policies in recent years to address climate change. Finally, this report will go into detail on a new analysis prepared by Atlanta Regional Commission (ARC) staff in 2013-2014 to develop a basic greenhouse gas inventory from residential electricity usage and automobile travel at a neighborhood level. This work will be the primary focus of the paper and contains the most detailed analysis related to climate change and planning-level decisions undertaken by ARC.

For readers interested in just the key results of this paper, an Executive Summary is also available.

What is Climate Change?

Scientists are confident that human activity since the Industrial Revolution has impacted the Earth's climate. Greenhouse gases, like carbon dioxide (CO_2), are emitted by burning fossil fuels for transportation, industry and electricity generation. Greenhouse gases prevent heat that would naturally be released by the atmosphere from escaping back into space. Once trapped, the heat impacts the normal flow of weather patterns across the planet causing changes collectively referred to as climate change. While there is large variability in the weather on a daily and monthly basis, it is important to not confuse those variations with the longer term trends associated with climate.

Climate change is the term used for long-term changes to the normal weather experienced at any one place as a result of either natural or man-made impacts on the atmosphere. Changes to temperature, precipitation, wind, etc. over time all constitute the impacts of climate change.

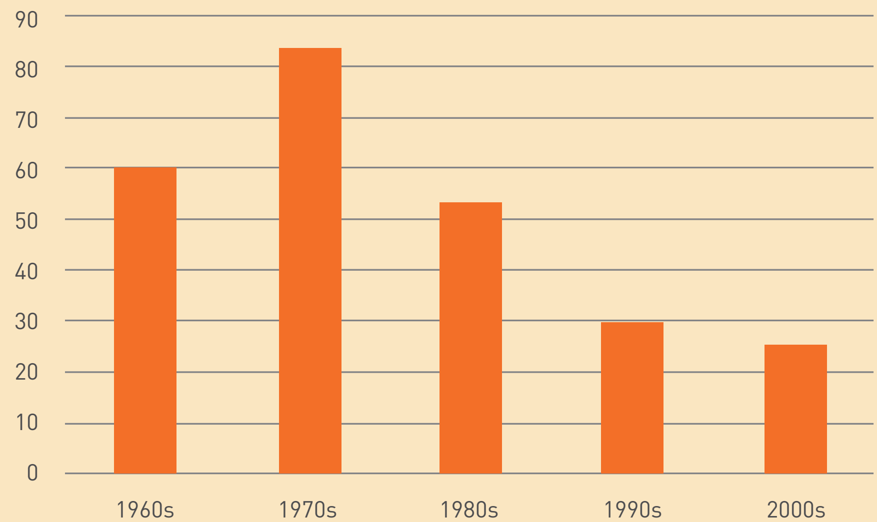
The EPA tracks 26 different key indicators of climate change. Their report, Climate Change Indicators in the United States,[5] is an excellent resource for understanding how scientists have come to a consensus that the climate is changing. The third edition of the report is available at **epa.gov/climatechange/science/indicators**.

Key indicators of a changing climate from EPA's report include:

- Based on records dating back to 1901, 7 of the 10 warmest years on record in the United States have occurred since 1998. The 10 warmest years worldwide have all occurred since 1998.
- From records dating between 1901 and 2013, 9 of the top 10 years for extreme one-day precipitation events have occurred since 1990.
- The decade from 2000-2009 saw twice as many record high temperatures as record lows.
- Sea levels have risen globally at a rate of six-tenths of an inch per decade since 1880.
- The average length of the growing season has increased by nearly two weeks across the lower 48 states since the year 1900. Spring is coming earlier and the autumn's first frost is coming later.

LOCAL ISSUE - Winter 2014 Cold Snaps

Figure A – Nights per Decade in Atlanta with Low Temperatures below 20°F



January and February 2014 are fresh on the minds of many Atlantans. Several cold spells culminated in a region-wide snowstorm stranding thousands of motorists on the frozen freeways and arterials. While the winter of 2013-2014 saw eight days in Atlanta with low temperatures below 20°F, the trend since the 1960s has been a steady decrease in cold winter nights.

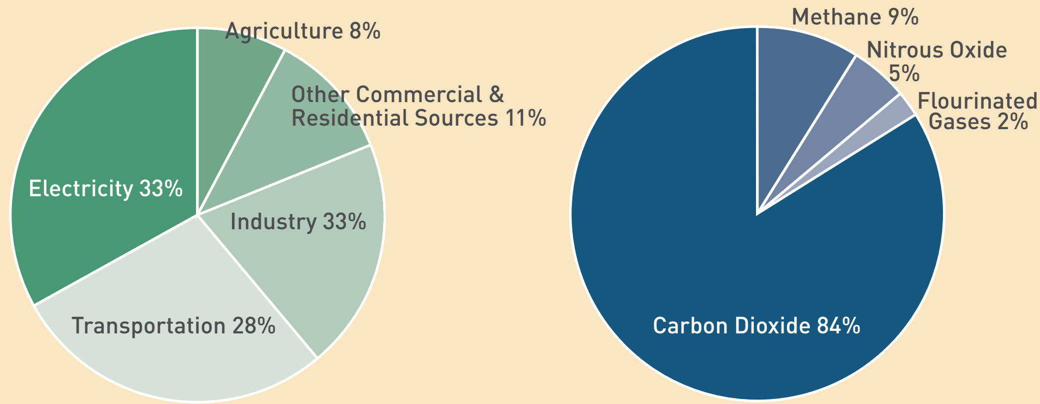
Source: Database from the National Climactic Data Center for the Atlanta Airport

Sources of Greenhouse Gas Emissions

Greenhouse gases are a product of our industrialized society. By understanding the sources of these gases it is possible to better understand how our daily activities contribute to climate change. Figure 1 illustrates the sources of greenhouse gases in the United States by sector and chemical compound. Electricity generation and transportation account for approximately 61% of United States greenhouse gas emissions.[6] In states like Georgia, with economies that are less focused on industry, electricity generation and transportation accounted for up to 80% of 2005 CO_2 emissions, according to a study completed by the Georgia Department of Natural Resources.[7]

The primary greenhouse gas released in the United States is CO_2, which accounts for more than 80% of greenhouse gas emissions. Other compounds, like methane, nitrous oxide and fluorinated gases account for the remaining emissions. CO_2 is often targeted when devising climate mitigation strategies since it is both the largest share of our greenhouse gas emissions and remains in the atmosphere for a long time. Each molecule of CO_2 can influence the Earth's greenhouse gas balance for centuries, compared to only approximately 12 years for methane, the second most emitted greenhouse gas.[8]

Figure 1: Sources of United States Greenhouse Gas Emissions by Sector and Compound in 2011



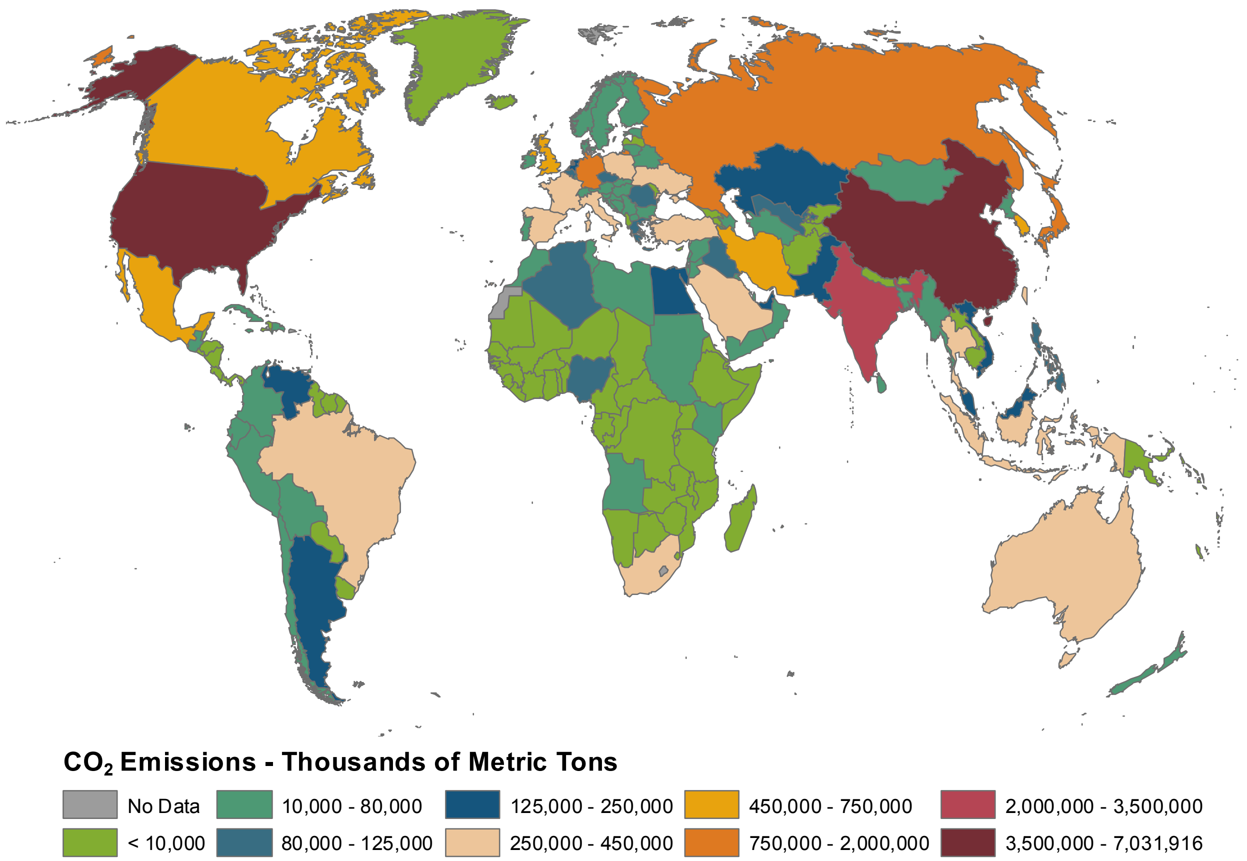
Source: US EPA[6,9]

Greenhouse Gas Emissions: A Global Issue

Unlike other pollutants humans put in the atmosphere that can cause nearby health impacts, greenhouse gases are not just a problem for the people living near the source of the emissions. Since some greenhouse gases, like CO_2, remain in the atmosphere for such a long time, they have an opportunity to mix and circulate around the globe. CO_2 released from the United States impacts everyone around the world as much as CO_2 released from Australia or Italy. It is for this reason that solutions to climate change are global in nature.

Across the globe, there is an uneven distribution of greenhouse gas emissions, illustrated in Map 1. Emissions vary based on variables such as: the population of a nation, the size of a nation's economy and the amount of energy that is derived from fossil fuels. As of 2008, the United States is the world's second largest emitter of CO_2, behind China.[10] The United States relies heavily on fossil fuels for transportation and electricity generation. In 2012, 68% of electric power generated in the United States was from fossil fuels.[11]

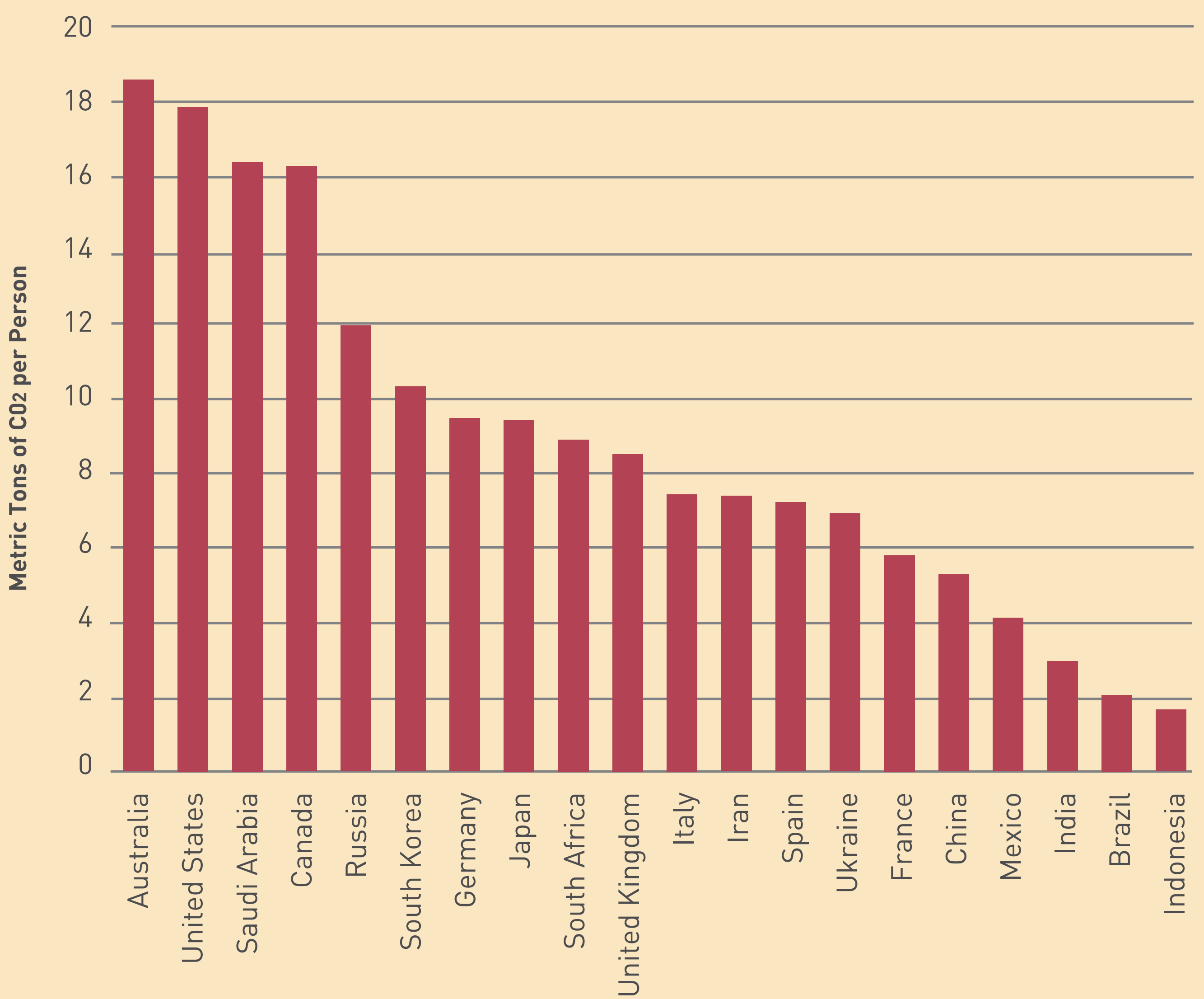
Map 1 – Global CO_2 Emissions by Nation in 2008



Source: United States Department of Energy, 2008 Data

Other large CO_2 emitters, like China and India, only produce a fraction of the CO_2 per person that the United States and many other developed nations do (see Figure 2). As of 2008, the per capita CO_2 emissions of the United States are more than three times higher than China's and more than six times higher than India's. United States per capita emissions are high even by developed country standards, with emissions twice as high as European nations like Germany and the United Kingdom.[12]

Figure 2 – Annual Per Capita Metric Tons of CO_2 Emissions for the Top 20 Emitters



Source: World Bank and United States Department of Energy, 2008 data

Climate change has become a hot topic issue in global equity. While the top 10 emitting nations produce more than 67% of global CO_2 emissions, the most significant impacts from climate change are forecasted to impact the world's poorest nations. Nations in Asia and Africa are particularly vulnerable.[13] These less developed nations produce the least amount of CO_2 and have the least developed response mechanisms to deal with changes in food production, water availability and public health issues anticipated over the next century as a result of climate change.

Climate Change Impacts in the Atlanta Region

Globally rising greenhouse gas levels impacts regional climate around the world in different ways. ARC's 2010 study "Taking the Temperature: Transportation Impacts on Greenhouse Gas Emissions in the Atlanta Region" summarizes some expected impacts from climate change in Georgia. This paper is available at **atlantaregional.com/climatechange**.

Since the release of "Taking the Temperature," the EPA has developed a comprehensive summary of expected impacts related to climate change over the next 80-100 years from an analysis of multiple climate models. In addition to (or echoing) the information provided by the EPA on expected impacts, some information in this report has come from the Southeast and Caribbean chapter of the third National Climate Assessment.[14] The National Climate Assessment is an interagency effort of the United States government required to be conducted every four years by the 1990 Global Change Research Act. On May 6, 2014, the United States Global Change Research Program released the 3rd National Climate Assessment. This report explores, in depth, the impacts of climate change in America today and in the future. Visit **nca2014.globalchange.gov** for more information.

It is important to note that no one has all the answers about climate change. Science on this issue is continually evolving as new and better models are developed. Key issues predicted to impact the Atlanta region based on the National Climate Assessment and EPA report relate to weather patterns, public health, water resources and transportation infrastructure.[15] Each of these topics is discussed below.

Changing Weather Patterns

Between 1960 and 2012… the region saw around 35 days per year with high temperatures over 90°F. Climate models predict that number could increase to over 120 days per year by 2080.

Average annual temperatures are projected to increase in the southeastern United States by 4 to 9°F by 2080. Most of the warming is expected to occur in the colder months. However, summer high temperatures are also predicted to continue to increase. Between 1960 and 2012 the Southeast Regional Climate Center[16] reports that the Atlanta region saw around 35 days per year with high temperatures over 90°F. Climate models predict that number could increase to over 120 days per year by 2080.

Precipitation is predicted to come with less frequency but with higher intensity, increasing the likelihood of cycles of floods and droughts. The percentage of precipitation falling in very heavy events from 1958 to 2012 has increased by 27% across the southeast US.[17]

Impacts on Public Health[18,19]

State and federal agencies have undertaken comprehensive studies on expected impacts of climate change on public health in the South. Public health in metro Atlanta could be adversely impacted by warmer temperatures. An increase in temperature-related health impacts is expected, including heat stroke and death. Warmer temperatures also correlate with poor summer air quality, which worsens respiratory ailments like asthma and leads to increases in cardiovascular disease and early mortality. Allergy sufferers could potentially expect worsened seasonal allergies, as warmer temperatures have been tied to increased pollen, mold and other allergens.

In addition, warmer temperatures have been linked to the spread of some bacteria and mosquito-borne illnesses, as well as an increased risk in water-borne and food-borne disease.

Impacts on Water Resources

The Atlanta region relies heavily on over-land water resources, such as lakes and rivers, for water supply. Warmer temperatures increase evaporation from reservoirs and plants, depleting ground water tables and water supply. Cycles of drought and flood will also impact water availability.

Since the beginning of reporting of weather conditions at Hartsfield-Jackson Atlanta International Airport in 1950, five of the driest years and three of the wettest years on record in Atlanta have occurred since 2000 (see Table 1). This pattern of extremes is projected to continue into the future. Water resources will continue to be challenged in the region by a quickly growing population and a small upstream watershed on the Chattahoochee River.

Table 1 – Ten Wettest and Driest Years on Record in Atlanta (since 1950)

Driest Years					
No.	Year	Rainfall (inches)	No.	Year	Rainfall (inches)
1	1954	31.8	**6**	**2001**	**38.39**
2	**2007**	**31.85**	7	1999	38.85
3	**2000**	**35.56**	**8**	**2011**	**39.22**
4	1955	36.43	9	1986	40.5
5	**2012**	**37.02**	10	1950	41.18

Wettest Years					
No.	Year	Rainfall (inches)	No.	Year	Rainfall (inches)
1	**2009**	**69.43**	6	1992	60.11
2	**2013**	**66.02**	7	1994	60.02
3	1975	66	8	1961	58.6
4	1989	63.31	9	1990	57.56
5	1964	60.13	**10**	**2005**	**56.43**

Source: National Climatic Data Center

Impacts on Transportation Infrastructure

More frequent and severe heat waves may require more investment in road and rail maintenance in the future. High temperatures can damage rail tracks and cause asphalt to soften and expand, causing potholes. In addition, warmer temperatures require airlines to reduce weight to ensure proper takeoff, causing cargo restrictions and flight cancellations.

In the future, ARC may have to program more money into roadway and rail maintenance to counter the impacts of climate change.

Increased extreme precipitation events can lead to more damage to road and rail infrastructure. Culverts can be overloaded and wash out roads above them. Roads can become flooded. Increased extreme precipitation events can also adversely impact air operations, causing flight cancellations and delays.

Economic Impacts

When considering the costs of climate change it can be more expensive to do nothing than to take actions to mitigate the causes. When summed across the globe, there is a strong economic argument for greenhouse gas mitigation strategies.[20]

Locally, the projected increase in flood/drought cycles as well as the projected overall decrease in soil moisture will likely impact agriculture and forestry throughout the southeast (see Local Issue – 2007 Georgia Drought box below). Warmer temperatures increase the likelihood of agricultural pest outbreaks, which also impact crops and forestry.

Warmer temperatures could result in increases in health care costs due to an increase in adverse health conditions. An increase in warmer summer days can also be reflected in an increase in summertime air conditioning electricity bills, which may be offset by savings in heating during the winter. More frequent drought periods could impact the cost of food for consumers.

LOCAL ISSUE - 2007 Georgia Drought

The year 2007 saw one of the worst droughts in Georgia's history. Overall, the drought was estimated to cause $1.3 billion in economic damages in agriculture.[21] In addition, the landscaping industry estimated losses of $1.2 billion, with around 12,000 jobs lost.[22] Other economic impacts that are hard to monetize include the loss of productivity in the timber industry, the impact to tourism around state lakes and the impact to agricultural venders (including retail of farm equipment).

Federal Action on Climate Change

Climate change has been an issue of earnest national debate since the early 1990s. The federal government's opinion on the issue has evolved over time, from the Clinton Administration through the Bush and Obama Administrations. A variety of bills have been proposed in Congress, from both parties, which would impact life in the Atlanta region. Executive orders have also been issued directing national agencies on greenhouse gas reductions and climate adaptation. These bills and orders have sought to reduce greenhouse gas emissions by a variety of means including: implementing a cap-and-trade program, improving vehicle and electricity generation efficiency, improving energy use efficiency, researching carbon sequestration and encouraging clean energy.

Clinton Administration

The primary climate-related issue during the Clinton Administration revolved around the United Nation's Kyoto Protocol. In 1998, the United States signed onto the Kyoto Protocol, an international treaty that aimed to reduce global greenhouse gas emissions. Despite the Administration's support, Congress never ratified the agreement. The Kyoto Protocol binds most developed country signatories to set greenhouse gas reduction targets, while not requiring much initial action from developing nations.[23] In 1997, the United States Senate passed the Byrd-Hagel Resolution which 1) disapproved of any international agreement that did not require developing nations to reduce emissions and 2) required all climate regulatory/legislative actions to be accompanied by a detailed list of costs and impacts to the United States economy.[24]

Bush Administration

During the Bush Administration, Congress introduced several bills to directly address climate change. In 2003 and 2005, the McCain-Lieberman Climate Stewardship Acts failed to receive enough votes in the United States Senate. The 2003 bill would have capped 2010 CO_2 emissions at 2000 levels. The bill was defeated in the Senate by a vote of 43-55.[25] The 2005 version of the bill would have required the federal government to play a key role in researching and developing new energy technologies. The bill would have also introduced a CO_2 cap-and-trade program.[26] This bill was defeated in the Senate by a vote of 38-60. Under the cap-and-trade provision of the bill, transportation, electricity generation, industry and commercial emissions would be capped at 2000 levels with the requirement to purchase offsets if emissions elevated above the required caps.

In 2007, the 110th Congress passed the Energy Independence and Security Act. This bill's stated goal was to move the United States towards energy independence, not limit greenhouse gas emissions. The final version of the bill focused on increasing the corporate average fuel economy (CAFE) standard, developing biofuels and improving energy efficiency in public buildings and lighting. These objectives all contributed to a reduction in greenhouse gas emissions as an additional benefit. This was the first bill to address fuel economy for non-truck vehicles since 1990.[27]

On the executive front, in 2003, EPA refused a petition from 12 states and several cities to regulate greenhouse gas emissions, citing a lack of authority from Congress.[28] In a landmark court case in 2007, the United States Supreme Court (Massachusetts v. EPA) held that greenhouse gases are pollutants that can be regulated under the Clean Air Act.[29] This decision led to EPA publishing a greenhouse gas endangerment finding in 2009 that determined that greenhouse gases pose a threat to current and future generation's health and welfare. The endangerment finding laid the foundation for EPA regulation of greenhouse gases beginning in earnest in 2011.

Obama Administration

Since the beginning of the Obama Administration, due at least in part to the 2007 Supreme Court decision, federal action on climate change has diversified. Bills have been introduced to Congress and the Office of the President has issued executive orders to reduce greenhouse gas emissions from a broad spectrum of sources.

Legislative Action

The American Clean Energy and Security Act would have required ARC to directly plan for climate change via mandatory transportation greenhouse gas reductions.

In 2009, the House of Representatives passed a bill meant to reduce greenhouse gas emissions. The American Clean Energy and Security Act was the first bill directly related to greenhouse gas reductions to pass either house of Congress, by a vote of 219-212. The bill was never taken up in the Senate. The key provisions of the legislation included requirements for renewable energy, energy subsidies, modernization of the electricity grid, more electric vehicles and energy efficiency measures in buildings and appliances. The American Clean Energy and Security Act also would also have established a cap-and-trade program with the goal of reducing emissions to 83% below 2005 levels by 2050.[30]

Provisions of the bill related directly to the work done at metropolitan planning organizations (MPOs), like ARC. The Act would have required transportation greenhouse gas emissions reductions for states and MPOs. MPOs would be required to set emissions reduction targets and strategies as part of the regional planning process. The targets and strategies were required, at a minimum, to[31]:

- be consistent with the models and methods outlined by the Clean Air Act
- address sources of transportation emissions
- include efforts to increase public transportation ridership
- include efforts to increase walking, bicycling and other nonmotorized transportation modes

Executive Branch Actions

The Obama Administration has acted directly, using executive orders, to reduce United States greenhouse gas emissions. In 2009 and 2011, the Administration set higher fuel economy standards for light duty vehicles. Fuel economy is required to double to a fleet average 54.5 miles per gallon by the year 2025, effectively halving the amount of greenhouse gases emitted per vehicle.[32]

In 2013, President Obama issued an executive order to encourage all federal programs to identify opportunities to encourage smarter, more climate-resilient investments. This order also sought to remove barriers and reform federal policies in regards to climate change.[33]

Also in 2013, the Administration prepared a Climate Action Plan,[34] with the goal to reduce greenhouse gas emissions and prepare the nation for the impacts of climate change. The Climate Action Plan commits the nation to a goal of a 17 percent reduction of greenhouse gas emissions below 2005 levels. Provisions of the plan include the deployment of clean energy, encouraging the development of new technology, and increasing energy efficiency.

Greenhouse gas emissions are decreasing… between 2005 and 2012 emissions have fallen by nearly 10%

Since the 2007 Supreme Court ruling, EPA has taken several steps to reduce emissions. In 2010, the Greenhouse Gas Reporting Program became law. This program requires that the top 85% of emitters report their annual emissions to the EPA. Over time the law requires that 100% of emissions be accounted for.[35]

In addition to the light-duty vehicle standards, EPA has worked on developing the nation's first-ever greenhouse gas emission regulations for heavy-duty vehicles. Combined, the new fuel economy standards are expected to save consumers $1.7 trillion in fuel costs by 2025 and reduce greenhouse gas emissions by six billion metric tons.[36]

In June, 2014, EPA initiated rulemaking for emission controls at existing power plants via the Clean Power Plan.[37] This proposed plan would cut emissions from the power sector by 30% from 2005 levels by 2030. States would have the ability to set how the reduction plan is carried out across sectors other than power generation.[38]

Numerous organizations in the private and public sectors have been partnering with EPA to voluntarily reduce their greenhouse gas emissions. These efforts include programs like Energy Star, the Center for Corporate Climate Leadership, GreenChill, and the Green Power Partnership.[39]

Greenhouse gas emissions are decreasing. Based off data from the EPA's most recent greenhouse gas emissions inventory, emissions between 2005 and 2012 have fallen by approximately 10%. The main contributors to the decrease were increases in energy efficiency, the continued switch from coal to natural gas for electricity generation, increases in fuel economy and limited new demand for passenger transportation.[40]

Local & Regional Initiatives on Climate Change

Both ARC and several local governing agencies in the Atlanta region have made commitments to learning more about climate change and/or reducing the impacts through mitigation and adaptation strategies. This section summarizes the state of climate change knowledge and activities in the Atlanta region.

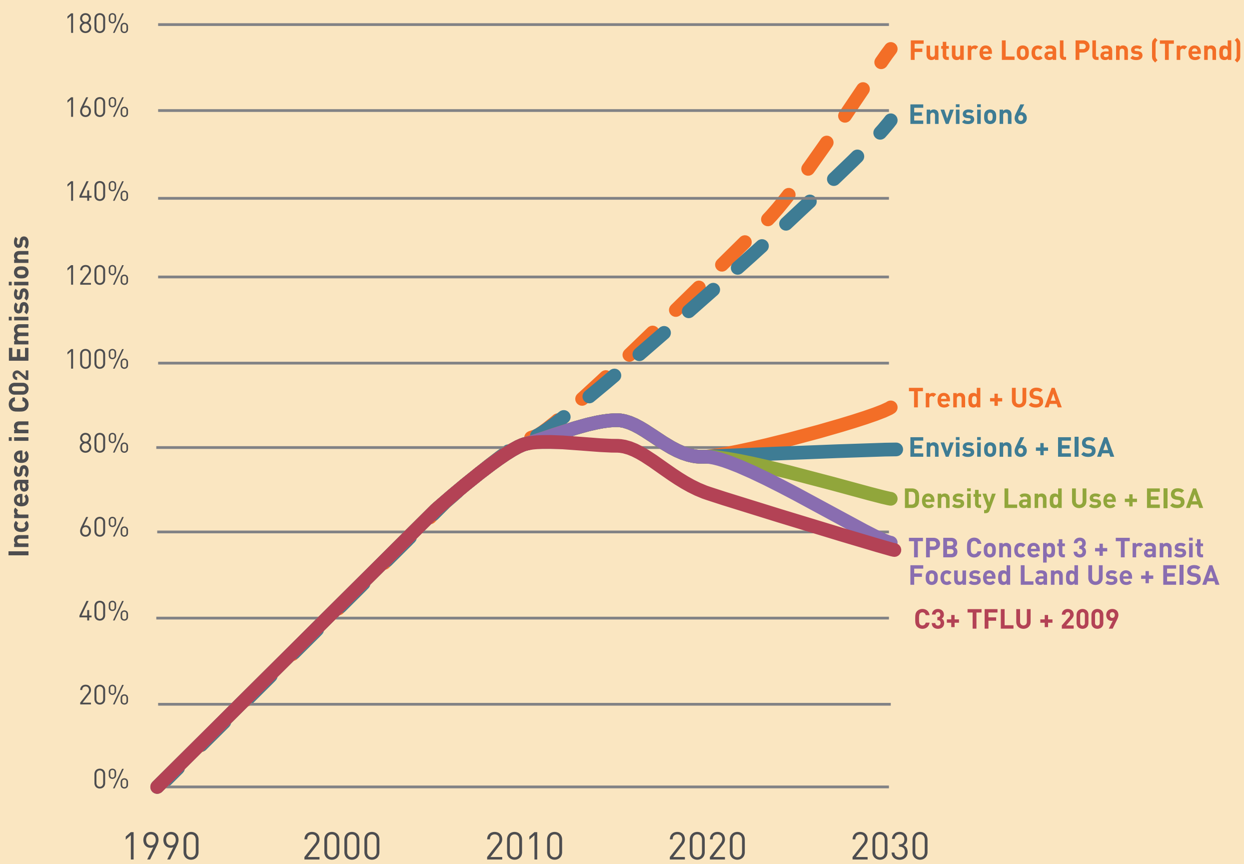
ARC Initiatives

ARC has been involved in the national conversation about transportation and greenhouse gas emissions since the middle 2000s. ARC staff have investigated future CO_2 scenarios and worked to include climate analysis in prior regional transportation plans. Below are some key milestones and activities in which ARC has been involved with regards to climate change, or programs that support a similar outcome.

Taking the Temperature: Transportation Impacts on Greenhouse Gas Emissions in the Atlanta Region

In 2010, ARC released a white paper[41] quantifying emissions from the transportation system as a whole. This study showed a range of possible emissions through the year 2030 based on possible changes to fuel economy and planning decisions. This paper introduced a variety of CO_2 reduction strategies aimed to provide readers with information on the state of the practice in CO_2 mitigation and land-use/transportation planning. Figure 3 highlights the key summary graphic from the work, illustrating possible future emissions scenarios in the Atlanta region. The paper concluded that improvements to fuel economy have the largest impact, but that planning level decisions can play a key role in reducing greenhouse gas emissions to meet CO_2 reduction goals.

Figure 3 – Summary of CO_2 Scenarios in ARC's White Paper "Taking the Temperature"



Key: Envision6 represented the region's last transportation plan, EISA is the acronym for the fuel economy standards enacted in 2007, TPB Concept 3 is the vision for regional transit in the Atlanta area and TFLU is an acronym for transit-focused land use and 2009 refers to the 2009 fuel standards

ARC's work with "Taking the Temperature" saw national attention and lead to an FHWA workshop on scenario planning and greenhouse gases in October, 2010. For more information on "Taking the Temperature" visit atlantaregional.com/climatechange.

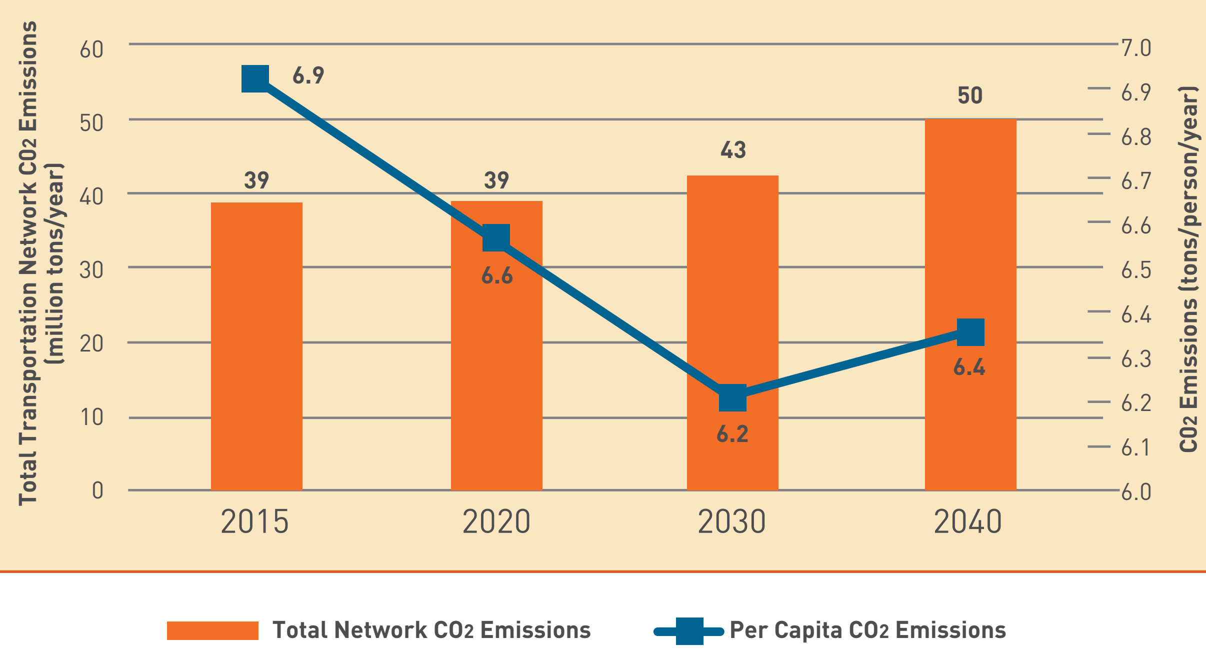
The overall trend in per capita transportation greenhouse gas emissions in the Atlanta region is decreasing primarily due to improvements in fuel economy and a reduction in driving.

PLAN 2040 Inventory and Project Evaluation

ARC sought to advance environmental sustainability as a key planning goal in the development of the PLAN 2040 Regional Development Plan in 2011. ARC included updated modeling of CO_2 emissions using the EPA's latest emissions model, MOVES, in the plan documentation. This information was updated along with the PLAN 2040 Update in March, 2014 (see Figure 4). Regional greenhouse gas emissions are projected to creep up between 2015 and 2040, while per capita emissions trend downward with an uptick between 2030 and 2040 due to continued population growth outweighing technology improvements in fuel economy.

In addition, ARC included a metric in the project-level benefit-cost analysis to account for the anticipated cost of CO_2 emissions in future years.

Figure 4 – PLAN 2040 Update (March 2014) Regional Transportation Plan CO_2 Emissions Projections



Livable Centers Initiative Program

The Livable Centers Initiative (LCI) is a program that awards planning grants on a competitive basis to local governments and nonprofit organizations to prepare and implement plans for the enhancement of existing centers and corridors consistent with regional development policies. The program also provides transportation infrastructure funding for projects identified in the LCI plans. LCI projects focus on improving transportation options, developing mixed use communities and improving air quality (see **atlantaregional.com/lci**).

Since its inception in 1999, the LCI program has assisted 113 communities with approximately $15 million in planning grants to devise strategies that reduce traffic congestion and improve air quality by better connecting households, amenities and workplaces. Another $184 million has gone to help recipients build transportation projects that help them accomplish their goals.

The primary goal of the LCI program is not focused on reducing greenhouse gas emissions. Instead greenhouse gas emission reduction is a co-benefit of the program. An assessment of the relationship between LCI communities and CO_2 emissions is presented in this report in the Greenhouse Gas Emissions by Neighborhood Characteristic Section and in Appendix 2.

Several communities in the region have policies in place to help direct development, similar to the LCI program. One example is the Gwinnett County 2030 Unified Plan.

Utility Climate Resiliency Study

In preparation for the 2016 Metropolitan North Georgia Water Planning District planning effort, the District is leading a proactive effort to assess the potential impacts of climate variability on the region's water resources and infrastructure planning. This study will provide utilities with a guide to identify and characterize potential climate variability impacts so that appropriate adaptation measures can be considered to increase utility resiliency in the face of extreme weather events. A variety of plausible climate scenarios will be evaluated, including historical weather data trends, existing climate models and paleo-climate data (tree-ring) to determine periods of droughts and extreme wet conditions.

Green Communities Program

The Green Communities Program is a voluntary certification program for jurisdictions of the 10-county Atlanta region to encourage local governments to become more sustainable. ARC developed the program to assist local governments in reducing their overall environmental impacts. Local governments earn points in 10 categories by implementing specific policies and practices that contribute to overall sustainability. The categories are:

- Green Building
- Energy Efficiency
- Green Power
- Water Use Reduction & Efficiency
- Trees and Greenspace
- Transportation
- Recycling and Waste Reduction
- Land Use
- Education & Outreach
- Innovation

Green Communities set an example by conserving energy, investing in renewable energy, conserving water and fuel, reducing waste and protecting and restoring the community's natural resources.

Local Government Initiatives

Many local governments and agencies in the Atlanta region have resource plans that advocate energy saving measures, sustainable development and good stewardship of natural resources. These plans, directly or indirectly, advance the platform of reduced greenhouse gas emissions. Below are a few plans and programs that metro Atlanta governments participate in that directly cite impacts on greenhouse gas emissions as part of their overall sustainability strategy.

MARTA – Green Energy & Sustainability

The Metropolitan Atlanta Rapid Transit Authority (MARTA) serves Fulton and DeKalb Counties with rail and bus service. The transit agency has made many efforts to improve environmental sustainability, including reducing its carbon footprint. To highlight a few key efforts:

- MARTA became a founding signatory of the 2009 Pilot Phase of the American Public Transportation Association's Sustainability Commitment. As a result of joining, MARTA completed a baseline carbon footprint.
- MARTA has committed to converting its bus fleet to compressed natural gas (CNG), which produces less greenhouse gas emissions as well as less air pollution. The authority operates over 400 CNG busses.[42]
- In 2009, MARTA won a federal grant worth $10.8 million to install shade structures with an array of 4,888 solar panels on the Laredo Bus Facility in Decatur. The facility generates 1.2MW of electricity. This is enough energy during peak sunlight hours to meet the facility's electricity needs and sell electricity back to Georgia Power's grid.[43]

City of Atlanta – Sustainability Initiatives

The city of Atlanta is involved in a variety of programs aimed at reducing energy use and reducing greenhouse gas emissions. To highlight just a few efforts:

- Atlanta Better Building Challenge – This program aims to reduce energy and water use by 20% in commercial buildings throughout the city by the year 2020.[44]
- Green building and retrofits – The city is working to increase energy efficiency by requiring all newly constructed city buildings to be certified at least LEED (Leadership in Energy and Environmental Design) Silver. In addition, the city is retrofitting existing buildings with more efficient lighting and energy savings measures.[45]

In 2009, the city of Atlanta released a report titled "Our Path to Sustainability," which highlights the city's vision for energy and climate change action. The report lays out a plan for the city that focuses on accounting for greenhouse gas emissions and laying the foundation for changes to city operations to reduce greenhouse gas emissions from buildings and transportation.[46]

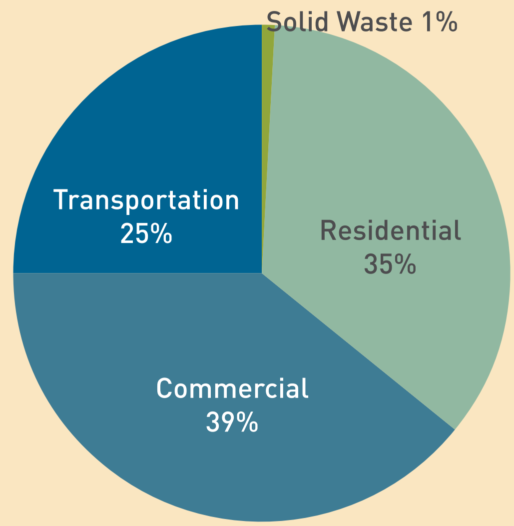
City of Decatur – Sustainability Assessment

The city of Decatur's 2012 Environmental Sustainability Plan[47] outlines how the community can grow in an environmentally friendly way, with goals to improve the natural environment, food and agriculture production, government best practices and the reduction of greenhouse gas emissions. The report outlines steps for the community to prepare a climate action plan with

city ordinances to reduce greenhouse gas emissions, such as anti-idling ordinances and the promotion of greener building practices. To kick-off the effort, the city created a greenhouse gas inventory (Figure 5).

Figure 5 - City of Decatur Greenhouse Gas Inventory

Greenhouse Gas Emissions (metric tons of CO_2)	2007	2009
Residential	94,908	92,285
Commercial	105,566	105,089
Transportation	66,768	66,000
Solid Waste	2,261	2,029
TOTAL	269,503	265,403
CHANGE		-2%



Source: City of Decatur

Bartow County – A Partnership for a Better Bartow[48]

Bartow County's Office of Environmental Programs oversees a committee made up of partner government groups, small businesses, industries, schools, non-profits and agriculture interests dedicated to preserving the county's resources. A Partnership for a Better Bartow was selected by the EPA in 2004 as the first county government in the nation to operate an Environmental Management System. An Environmental Management System is a framework that helps an organization achieve its environmental goals through consistent control of its operations.[49] The clean air mission statement for the partnership directly refers to the reduction of greenhouse gases to limit the impacts of climate change as a key goal of the program.

DeKalb County – DeKalb's Green Focus[50]

For more information on DeKalb's efforts visit co.dekalb.ga.us/greenfocus

DeKalb County's Natural Resource Management Office maintains a website that informs citizens of the efforts the county government is making to reduce energy usage. The website also provides information about the programs DeKalb County is undertaking, many with EPA support, to reduce greenhouse gas emissions. Some of these programs and policies include: Energy Star audits of energy usage in more than 160 buildings in the county, a "Lights Out/Power Down" policy for government buildings and a cool roofs program.

DeKalb County's sanitation division developed the first local renewable energy source at the Seminole Road landfill. Through an EPA Green Energy Partnership, DeKalb County has powered more than 70 buildings, including the Gregory A. Adams Juvenile Justice Center, with 100% renewable energy since 2009.

United States Conference of Mayors Climate Protection Agreement[51]

Several mayors in the Atlanta region have signed on to the United States Conference of Mayors Climate Protection Agreement. These mayors joined over 1,000 cities representing over 86 million people and agreed to take the following actions:

- Strive to reduce emissions through actions that contain sprawl, restore urban forests and support public information campaigns
- Lobby the state and federal governments to enact policies to reduce greenhouse gases
- Urge the federal government to pass bipartisan greenhouse gas reduction legislation

As of April, 2014, the mayors (or previous mayors) of Alpharetta, Atlanta, Decatur, East Point and Roswell had signed the agreement.

Energy Star Challenge

A number of communities in metropolitan Atlanta participate in the EPA Energy Star Challenge. The goal of this challenge is to reduce greenhouse gas emissions and save money by improving energy efficiency by 10% in all buildings nationwide.

122 organizations in Georgia are committed to the Energy Star Challenge. A full list of participants from private and public entities is available on the Energy Star website.[52] The local governments committed to the challenge include: Bartow County, the City of Alpharetta, the City of Conyers, the City of Doraville, the City of Riverdale, the City of Roswell, DeKalb County, Fulton County Schools, Gwinnett County Schools, Gwinnett County, Marietta City Schools and the City of Milton. In addition to the local governments listed above, the State of Georgia has committed to the challenge.

In 2014, metro Atlanta ranked 3rd in the nation for the highest number of Energy Star certified buildings at 318.

In 2014, metro Atlanta ranked 3rd in the nation for the highest number of Energy Star certified buildings at 318.[53] EPA estimates that these buildings use an average of 35% less energy and save more than $53 million annually in energy costs. The energy savings in the 318 Energy Star buildings offset greenhouse gas emissions equal to 52,500 homes.[54]

Introduction to the Greenhouse Gas Inventory Study

Previous efforts by ARC to quantify greenhouse gas emissions focused at a regional level, with little detail about how community characteristics impact emissions directly. This study calculates the Atlanta region's contribution to climate change, as measured by CO_2 emissions produced by transportation and household energy use, at a community scale. Combined, transportation and electricity generation (for all purposes, not just household use) account for approximately 60% of United States greenhouse gas emissions.[55] If a community decides that climate action is a policy worth pursuing, then the community's planners, citizens and decision-makers need to understand what demographic, design and transportation patterns lead to higher CO_2 emissions in order to make more informed decisions on how to shape their community in the future.

There are many existing publications that relate household characteristics and travel patterns to CO_2 emissions.[56,57,58] For this analysis, ARC staff combined local electricity usage data from Georgia Power, population data from the United States Census Bureau and transportation information from the ARC regional travel model to determine how much CO_2 is produced at a neighborhood scale. By developing tools to determine emissions at a local level, the goal is for planners, policy-makers and citizens to understand what impact community design has on CO_2 emissions.

Methodology

The emissions produced by household electricity usage and personal automobile travel were examined to develop a baseline CO_2 emissions inventory for the Atlanta region. Automobile travel includes car, light truck and SUV travel. Each analysis was performed separately and then the results were combined to provide a snapshot of a key component of regional CO_2 emissions for the year 2010.

Automobile CO_2 Emissions

In addition to CO_2, car and truck exhaust contains unhealthy chemicals that have been shown to worsen respiratory diseases such as asthma and cause certain types of cancer.

Transportation accounts for approximately 28% of national greenhouse gas emissions.[59] Cars, trucks and buses burn fossil fuels, like gasoline and diesel, in their engines, releasing CO_2 in their tail-pipe exhaust. Rail transit in the Atlanta region, like the MARTA system and the Atlanta Streetcar, rely on electricity generated at power plants that heavily rely on burning coal and natural gas.

A more complete explanation of the methodology used to develop the transportation CO_2 emissions is available in Appendix 1. The subsections below outline the data sources used for the study and some of the limitations associated with those data.

Data Sources

ARC maintains a transportation model that simulates daily travel of individuals in a 20-county area of metropolitan Atlanta. The model breaks the counties up into approximately 2,000 smaller areas called traffic analysis zones (TAZs). The transportation model was run for the year 2010 and automobile trip distances by each individual's home TAZ were calculated. This method links CO_2 emissions to the home TAZ of the trip-taker instead of the TAZ that the trip passes through. All trips taken from any starting location are attributed back to the trip-taker's home TAZ. Longer and/or more frequent trips result in more CO_2 emissions.

Data Limitations

Transit emissions are not considered in this study. Due to the way the travel model processes transit trips, it is not possible to accurately account for the distance of each transit trip in the region. However, transit emissions per mile are lower than automobile emissions, and transit trips in the Atlanta region tend to be shorter than personal automobile trips, only accounting for 3% of the total distance traveled daily. This analysis underestimates transportation-related CO_2 emissions in areas with high transit ridership, but this is expected to have little impact on the analysis results.

Interested in decarbonizing your transportation? Walking and biking are the only nearly 100% carbon free ways to travel. The Atlanta Bicycle Coalition has tips for making the transition at atlantabike.org

Analysis Outputs

Per person and per household transportation CO_2 emissions were evaluated. The values were calculated for each of the approximately 2,000 TAZs in the ARC transportation model. The results were compared to neighborhood design characteristics such as household distance from major activity/employment centers, multimodal transportation options and regional trip attractors, like shopping areas, schools and universities. The results are presented in the Emissions Inventory Results section.

Residential Electricity CO_2 Emissions

A key component of Atlanta's total CO_2 emissions comes from the burning of fossil fuels to provide our households with electricity. These CO_2 emissions are associated with the energy used to heat and cool living space, power electronics and light residences.

A more complete explanation of the methodology used to develop the residential electricity CO_2 emissions is available in Appendix 1. The subsections below outline the data sources used for the study and some of the limitations associated with those data.

Data Sources

Southern Company, Georgia Power's electric holding company, provided total annual energy use in kilowatt-hours (kWh) for the year 2010. This data was provided for 178 ZIP codes in a 19-county area of the Atlanta region. The database included the number of billed premises within each ZIP code and how much energy went to residential, commercial and industrial uses. Southern Company billed approximately 1.1 million of the 2 million households in the 19-county area, which accounts for approximately 55% of households. The rest of the households in 2010 were billed by other providers. In some ZIP codes, a small percent of the total households were billed by Southern Company. ZIP codes were excluded from the analysis if Southern Company billed less than 100 premises. This threshold maintains a CO_2 estimate margin of error ≤10%. Of the sampled ZIP codes, 90% had enough billed premises to provide a margin of error ≤5%.

The other significant data used for the residential portion of the study came from the 2007-2011 American Community Survey from the United States Census Bureau. This database provides information on neighborhood characteristics and design, such as: number of housing units per multifamily development, age of household structures and average number of bedrooms per household. This information was used to compare energy usage to key indicators of urban design to better understand which household characteristics result in more or less CO_2 emissions.

Georgia Power offers a program for consumers to buy green energy. The energy's source is certified by an independent program. Visit georgiapower.com/earthcents to learn more.

Data Limitations

Southern Company does not bill every household in the region. As a result, it is not possible to develop a total CO_2 emissions inventory for the Atlanta region on this data alone. Therefore, inventories are presented on per person or per household levels.

In some areas of the Atlanta region, natural gas is used to heat households and water. ARC did not receive any information on natural gas usage. The distribution of natural gas availability is not uniform in the region. Map 18 in Appendix 2 illustrates the share of households that use natural gas. Averaged across the region, 63% of households use natural gas. Areas with high amounts of natural gas heating have lower electricity usage, and therefore their total residential CO_2 emissions are being underrepresented.

Not every variable that can be tied to household CO_2 emissions was examined in this project. Literature reviews often indicate that household income, for example, is a key predictor of CO_2 emissions. Variables, like income, that do not provide insight into community design or planning decision-making were omitted from the study.

Analysis Outputs

There are two key outputs from this analysis. First, for every ZIP code that Southern Company billed more than 100 premises, ARC staff was able to determine an electricity-derived per household and per capita CO_2 emission. Second, by looking at the Census data, and using statistical tools, ARC staff was able to draw conclusions about what type of neighborhood characteristics lead to higher or lower CO_2 emissions. The results are presented in the Emissions Inventory Results section of this paper.

Combined CO_2 Emissions

To get a final CO_2 inventory for the Atlanta region, the per household and per person electricity emissions were assumed to be uniform within a ZIP code. These numbers were then added to the per household and per person transportation emissions for each individual TAZ, which is a smaller geographic unit than a ZIP code. This method allows the combined results to be viewed at a finer geography that maintains the detail of the transportation emissions.

Emission Inventory Results

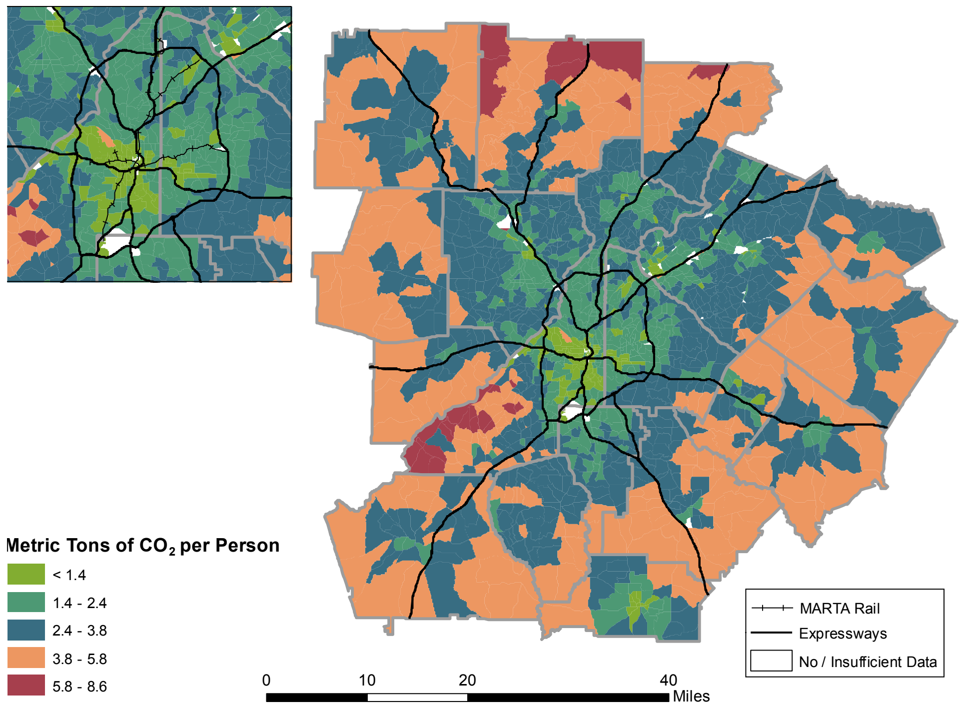
This section outlines the results of the CO_2 emissions inventories. The results are broken down into an automobile, a residential and a combined inventory section. The next section of the paper, titled Greenhouse Gas Emissions by Neighborhood Characteristics, explores some of the neighborhood level Census and transportation indicators that lead to the results outlined in these emissions inventories.

Data for emissions are presented in both a per person and a per household level. The emissions themselves are a result of the key transportation and residential indicators presented below and not a result of the way data are presented (on a per person or per household level). A full discussion of the differences in looking at per person or per household CO_2 emissions is presented in the Key Findings section of the paper. In short, looking at emissions on a per household level allows us to focus more directly on the planning-level decisions that lead to variations in CO_2 emissions and are the focus of most subsequent analyses.

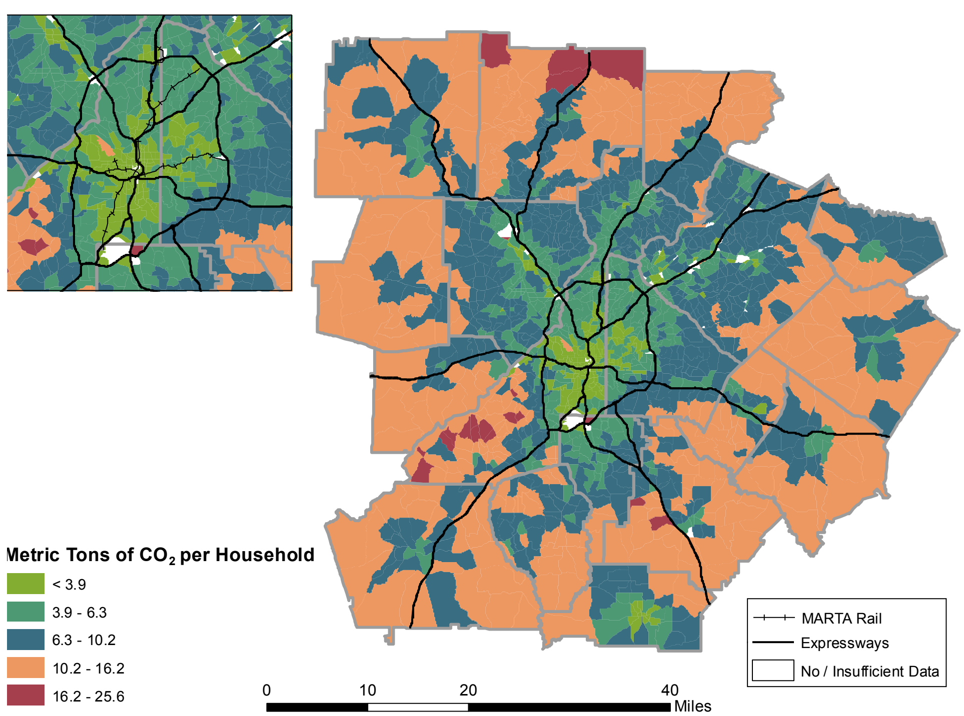
Automobile CO_2 Emissions

Maps 2 and 3 illustrate per person and per household inventories of CO_2 emissions as a result of automobile travel in the Atlanta region.The transportation CO_2 emissions are minimized in the center of the region, in regional town centers, near MARTA rail corridors and along major expressways. Since transportation emissions are only a result of the distance traveled by car, areas with lower emissions are producing less or shorter automobile trips than areas with higher emissions.

Map 2 – Annual Automobile CO_2 Emissions per Person by Traffic Analysis Zone



Map 3 – Annual Automobile CO_2 Emissions per Household by Traffic Analysis Zone



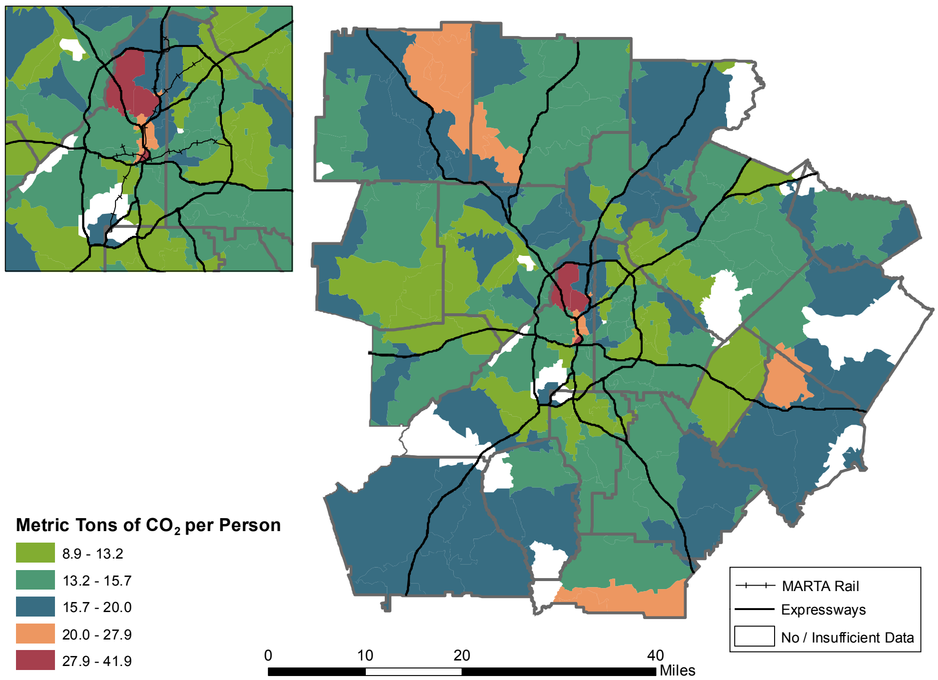
Residential Electricity CO_2 Emissions

Maps 4 and 5 illustrate per person and per household CO_2 emissions in the Atlanta region calculated from household electricity usage. Unlike automobile emissions, the pattern here is quite different for the two different maps.

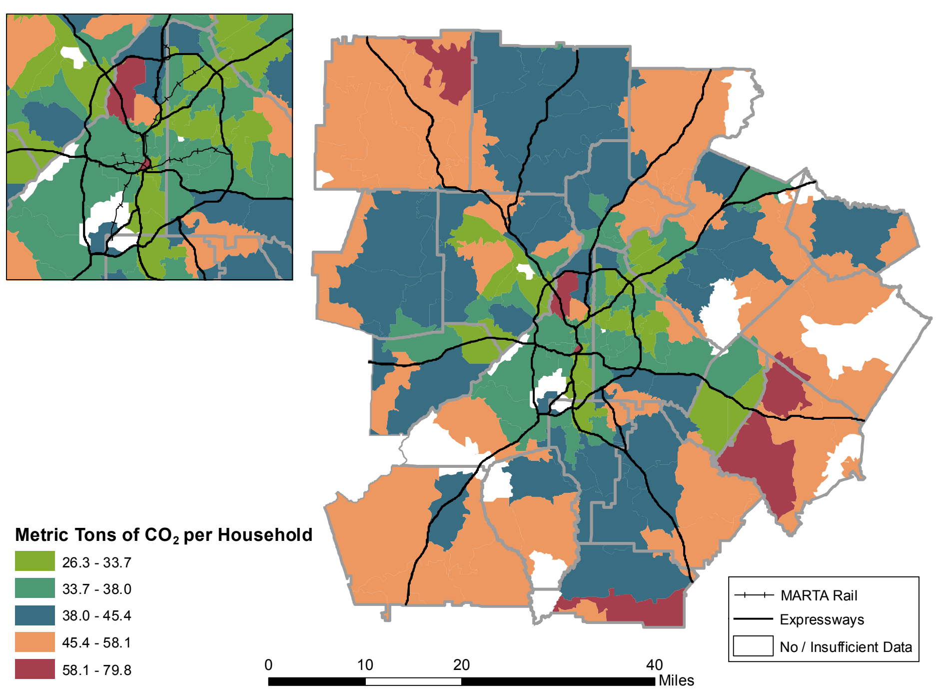
Residential CO_2 emissions per person are lowest in communities just around the perimeter, in southeast Paulding County and in Rockdale County. Residential CO_2 emissions per household are lowest inside the perimeter, in Rockdale County and along the I-75 and I-85 corridors in Cobb and Gwinnett Counties, respectively.

The differences can be explained by looking at key demographic and neighborhood design characteristics, explored further in the Greenhouse Gas Emissions by Neighborhood Characteristic section of this document.

Map 4 – Annual Residential Electricity CO_2 Emissions per Person by ZIP Code



Map 5 – Annual Residential Electricity CO_2 Emissions per Household by ZIP Code

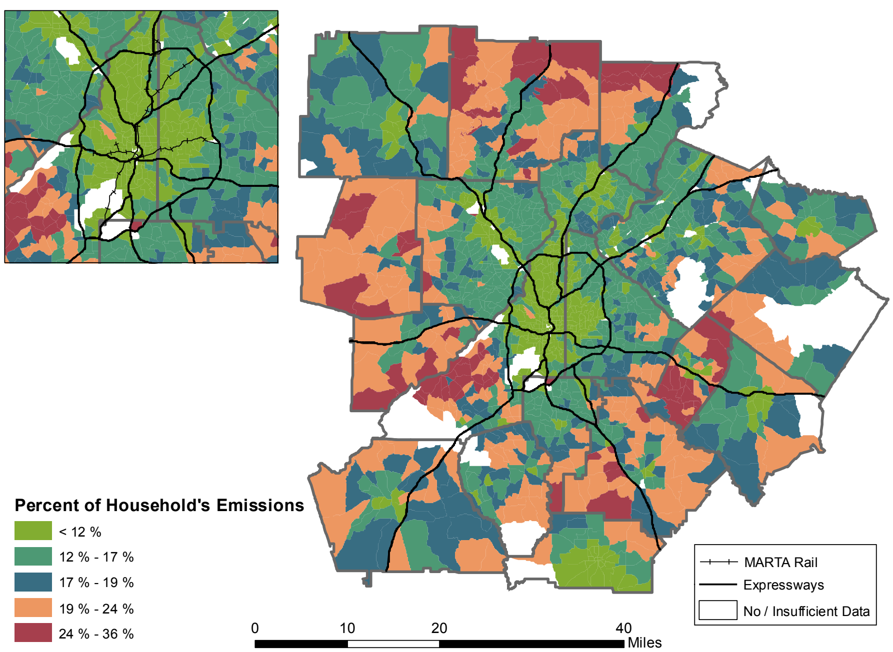


Combined CO_2 Emissions

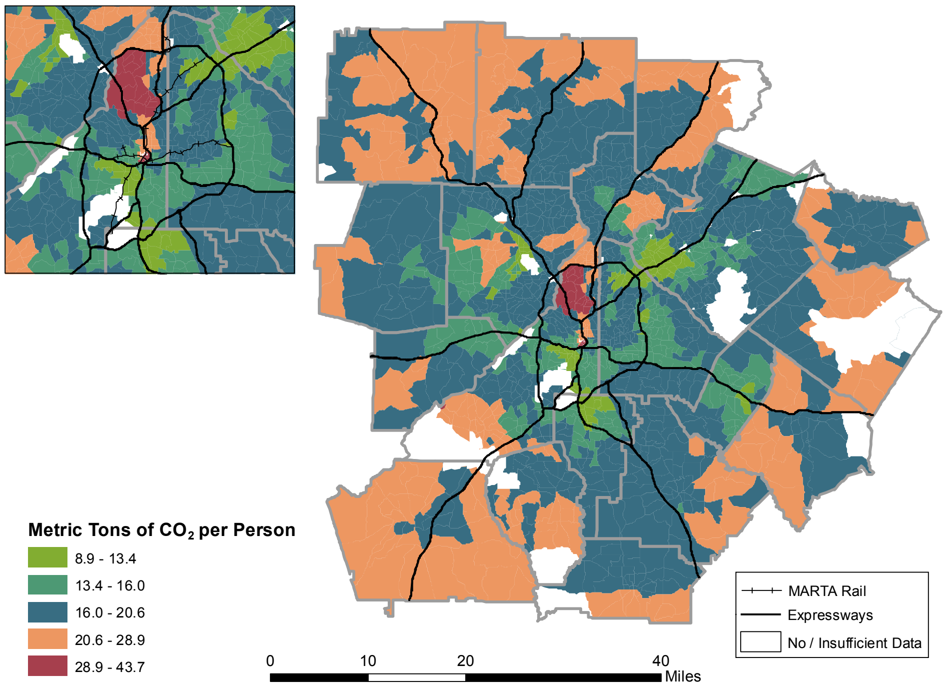
Total CO_2 inventories are calculated by summing the residential electricity and automobile emissions inventories on a per person and per household basis. Maps 7 and 8 illustrate those results.

Residential electricity CO_2 emissions drive the total emissions score. Areas closer to the center of the region, regional activity centers and town centers tend to have a lower portion of their total carbon footprint from automobiles relative to household electricity usage. Automobile-generated emissions account for approximately 15% of the region's share of total CO_2 emissions. Map 6 illustrates the share of total CO_2 attributable to transportation by each traffic analysis zone. Areas on the edge of the region, or in locations with few jobs and services, tend to have a larger share of their total CO_2 emissions from transportation. These relationships are explored in the Greenhouse Gas Emissions by Neighborhood Characteristics section of the paper.

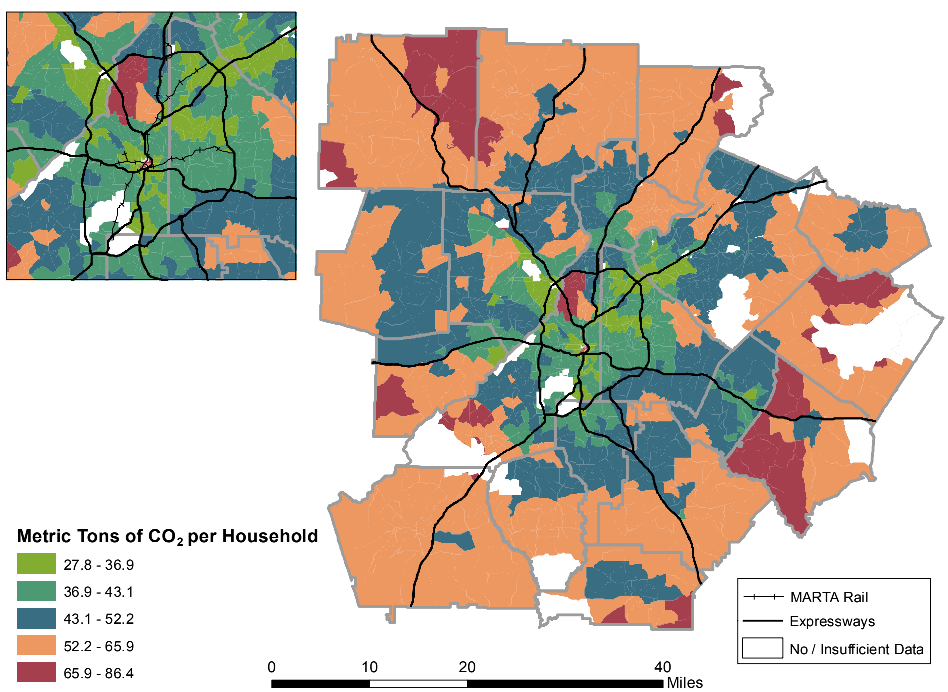
Map 6 – Percent of Household CO_2 Emissions from Automobile Usage



Map 7 – Annual Combined CO2 Emissions per Person



Map 8 – Annual Combined CO2 Emissions per Household



Greenhouse Gas Emissions by Neighborhood Characteristics

Looking at neighborhood design and household characteristics helps to better understand the emissions inventories. Using geographic information systems (GIS) and statistical software, analysts can examine which aspects of certain neighborhoods correlate to communities with lower or higher CO_2 emissions. This information can be helpful to citizens, planners and policy makers in communities that may wish to target greenhouse gas reductions as part of a sustainability program.

Table 2 breaks out the neighborhood level key indicators with regard to their impact on CO_2 emissions in the region. Transportation and residential emissions are correlated to key indicators separately, due to differences in the geographies of measurement. The table includes information on whether the indicator primarily impacts automobile or residential emissions and provides the direction of the correlation and the magnitude of the potential impact on CO_2 emissions. In other words, whether you should expect a decrease or an increase in the CO_2 emissions per household if you increase the indicator's presence in the community. A ▲ indicates an increase in the indicator would lead to an increase in CO_2 emissions while a ▼ indicates that an increase in the indicator would lead to a decrease in CO_2 emissions. For example, the amount of multi-family housing is negatively correlated with residential CO_2 emissions; therefore an increase in multi-family housing relates to a decrease in residential CO_2 emissions per household in that community.

The presence of multifamily housing, the size of residences, a community's residential density, the community's walkability, multimodal accessibility, the distance to regional activity centers and a community's share of transit ridership were the most significant indicators of greenhouse gas emissions per household.

Table 2 – Key Neighborhood Indicator's Impact on CO_2 Emissions

Key Indicator	Description	Transportation Focused	Residential Focused	Strength of Relationship to per Household CO_2 Emissions*
More multi-family housing	The amount of multi-family housing in community		✔	▼▼
More people per household	The average number of people living in a household		✔	▲
Larger size of household	Physical size of a residence as measured by bedroom count		✔	▲▲
Older age of property	The age of a residence		✔	▼
Higher population density	The number of people per square mile	✔	✔	▼▼
Higher Walkability Index	Measure of the walkability of a community	✔		▼▼
Higher Multimodal Access Index	Measure of how many transportation options to employment exist in a community	✔		▼▼▼
Higher Jobs Housing Balance of Community	The ratio of the number of jobs to the number of housing units	✔		▼
Longer distance to Regional Activity Centers	The proximity of a community to major employment centers	✔		▲▲
More miles of Transit Ridden per Day by the Community	The relative amount of distance people in a community travel by transit	✔		▼▼
More distance to GRTA Express Park & Ride	The proximity of a community to GRTA park and rides	✔		▲

* The number of ▲ or ▼ signs denotes the strength of the relationship from 1 to 3 symbols for weak, medium and strong based on the size of the correlation coefficient. See Appendix 2 for more details, including the calculated correlations.

Three additional neighborhood descriptors were evaluated for their relationship to household automobile CO_2 emissions. Table 3, below, illustrates the average household transportation emissions in communities directly adjacent to a MARTA transit station, part of the LCI program or studied as part of the 2013 Walkable Urban Places (WalkUPs).[60] These values are compared to communities where the indicator is "absent" to stress the relationship between the indicator and CO_2 emissions. The communities are illustrated in Appendix 2, Map 19. Overall, communities with good transit access and good walkability have much lower household automobile CO_2 emissions. More trips in these communities are walking, biking or transit, and trips taken by car are generally shorter than in non-LCI, non-transit accessible communities.

Table 3 – Neighborhood Descriptors and Transportation CO_2 Emissions per Household

Indicator	Average Automobile CO_2 Emission per Household (metric tons)		
	Present	Absent	Percent Difference
MARTA Transit Station in Community	3.0	7.4	59 %
LCI Community	3.8	7.8	51 %
2013 "WalkUPs"	2.8	7.6	63 %

Note: "absent" indicators refers to the absence of the indicator in the TAZ

A more detailed analysis of the statistical relationship between the studied indicators and CO_2 emissions is presented in Appendix 2.

Key Findings

Communities interested in reducing their CO_2 emissions can gain insight through an understanding of the analysis in this report. CO_2 emissions are directly related to the types of communities in the region. Planners, citizens and decision makers that have greenhouse gas emissions reduction as a policy goal for their communities should consider evaluating the presence of the key indicators in their communities.

Interested in learning more about reducing household energy usage? Check out the U.S. Department of Energy's website at: energy.gov/energysaver

Residential

The most important residential indicators of CO_2 emissions are (in order):

- Presence of multifamily housing
- Size of the residences
- Density of housing
- Number of people per household

Multifamily residences offer energy-saving benefits from shared walls with neighbors, which helps reduce the loss of heat in the winter and cool air in the summer to the outside world. Multifamily residences also tend to be physically smaller than single family houses. Overall, heating and air conditioning residences (nationwide) accounts for nearly 50% of household energy use[61].

The size of a residence directly relates to how much energy it takes to heat/cool. Communities that include multifamily housing help reduce residential electricity CO_2 emissions.

The number of people living in a household is also an important indicator for greenhouse gas emissions. It takes a certain amount of energy to heat or cool a house regardless of the number of people living there. Greenhouse gases do not increase at a 1 to 1 ratio with the number of people living in a household. Nuclear families, multi-generational households and people living with roommates all contribute to communities with lower CO_2 emissions per person.

Ultimately, household residential emissions are directly related to how much energy is used in residences. Between 1978 and 2005, the total amount of electricity used per household has not changed, despite a nearly doubling in the energy used by electronics.[62] Most of this increase has been offset by efficiencies in insulating households.

Community zoning that allows for smaller residences can be a useful tool in helping reduce electricity-related CO_2 emissions.

Transportation

The most important transportation indicators of CO_2 emissions are (in order):

- Multimodal accessibility
- Transit share
- Distance to regional activity centers
- Population density
- Neighborhood walkability

Driving habits impact your greenhouse gas emissions. For tips on reducing emissions and saving money on fuel, visit greenercars.org/drivingtips.htm

By increasing transit share, multimodal accessibility and walkability people are less likely to drive their automobiles. While a community cannot directly change its proximity to major activity centers, which are key attractors for work and shopping trips, communities can make decisions that encourage the development of more jobs in their community.

Communities with a transit station produce at least 50% less CO_2 emissions from transportation than those without one. These communities tend to be more walkable and have more employment. By increasing transit use within communities, not only are more options provided to move people around the region, but CO_2 emissions are reduced.

LCI communities produce about 50% less CO_2 emissions than non-LCI communities. The LCI program is focused on building mixed-use communities with good transportation and housing options. LCI communities rely less on automobiles for transportation, thereby reducing greenhouse gas emissions.

ARC's prior paper "Taking the Temperature" also outlines key strategies for reducing transportation related greenhouse gas emissions that are not related to neighborhood design. These key strategies include: improving vehicle efficiency, enhancing on-road operating efficiency by reducing congestion and smoothing speeds, decreasing the distances driven and reducing the carbon content of fuels.[63]

The Difference Between per Person and per Household CO_2 Emissions

Emissions are a result of the key transportation and residential indicators presented above and not a result of the way data are presented (on a per person or per household level).

Emissions per household are minimized in areas with fewer people living in each household. For example, one or two person households are generally physically smaller (requiring less energy to heat and cool) and have fewer users of appliances and electronics. In addition, smaller households are more likely to be in multi-family developments, providing benefits in heating/cooling from shared walls. As a result, areas like in-town Atlanta, Decatur, Cumberland, Southwest Gwinnett and Rockdale counties all have low CO_2 emissions per household.

Emissions on a per person level are reduced in areas with more people living in households. These households, although producing more absolute CO_2 emissions than households in other areas of the region, see multi-person benefits due to the fact that emissions do not grow at a one-to-one rate with each additional person in a household. Conversely, areas that have a very low number of people per household tend to have higher per person CO_2 emissions. These observations are then tempered by the design characteristics of a community. As a result, some of the neighborhoods that ring the perimeter and in suburban areas with a larger share of children, smaller house sizes and transportation options have low CO_2 emissions per person. For more information on the spatial distribution of multi-person households and children in the Atlanta region, see Maps 16 and 17 in Appendix 2.

Some communities in metropolitan Atlanta minimize emissions per household and per person. These communities, like southwest Gwinnett County, central DeKalb County and southeast Atlanta mix the benefits of good transportation access to major employment centers, with the presence of multi-family housing in relatively small residences with multiple people per household. The location of these communities proves that sustainable living is not just focused on in-town neighborhoods, but can be found across the region with the right mix of conditions.

Co-Benefits of Planning-Related CO_2 Mitigation Strategies

There are many positive co-benefits to building climate-smart communities beyond curtailing global climate change. Many of the planning-related strategies have been tied to building better communities. Even if the overwhelming majority of scientific knowledge pointing to the existence of climate change turns out to be incorrect, investments in CO_2 mitigation strategies reap positive benefits in the areas of improved air quality, safety, health and economy. Some of these key co-benefits are outlined below.

Air Quality

In 2011, the World Health Organization looked at the health impacts of the major transportation CO_2 mitigation strategies proposed by the Intergovernmental Panel on Climate Change. The study found that climate change mitigation strategies are mostly tied to positive health outcomes. Policies with the greatest health benefits include those that increase the accessibility and quality of public transportation and active transportation, defined as human-powered transportation like biking and walking.[64] Land use measures that support these types of transportation, like increased density and traffic calming, are an important component of any greenhouse gas mitigation strategy.

Poor air quality has been tied to approximately 50,000 premature deaths in America each year.

By taking policy action to reduce our reliance on personal automobile travel while increasing transit, walking and bike trips, we help improve air quality. Poor air quality has been tied to approximately 50,000 premature deaths in America each year. And the price tag associated with treating air quality-related worsened illnesses (such as asthma, emphysema and chronic bronchitis)[65] is over $150 billion annually.[66] Poor air quality is expected to worsen with the warmer temperatures anticipated in future decades as a result of climate change. A 2011 report by the Union of Concerned Scientists estimates that by 2020 Americans will be paying an additional $5.4 billion in air quality impacts due to warmer summer temperatures.[67]

Safety

In 2012, according to the Georgia Department of Transportation's records, 61,703 people were injured and 453 people were killed on roadways in the 18 counties that make up the ARC metropolitan planning area. CO_2 mitigation strategies tied to a reduction in automobile trips have also been tied to a decrease in road traffic injuries. Traffic calming strategies (like speed tables, medians and curb extensions) can help to provide a more bicycle and pedestrian friendly environment, which promotes those carbon-free modes of travel. In addition, promoting traffic calming strategies has been shown to reduce the number of automobile-pedestrian crashes by up to 15%.[68]

Healthy Living

A 2012 study published in the Journal of Preventative Medicine found that only about 25% of Americans participate in active transportation. Those that do participate in active transportation have a lower Body Mass Index (BMI), lower waist circumference and lower odds of developing diabetes and hypertension.[69] People who regularly walk as a mode of transportation are also three times more likely to meet the CDC recommended 150 minutes of moderate-intensity cardiovascular exercise per week than those that only drive.[70]

Regular physical activity has also been tied to a reduction in depression, arthritis and osteoporosis. Exercising has been linked to an increase in energy and an improvement in mood and better sleep.

By building communities that support active transportation we achieve the goal of reducing CO_2 emissions while simultaneously promoting healthy lifestyles and avoiding billions of dollars of medical intervention.

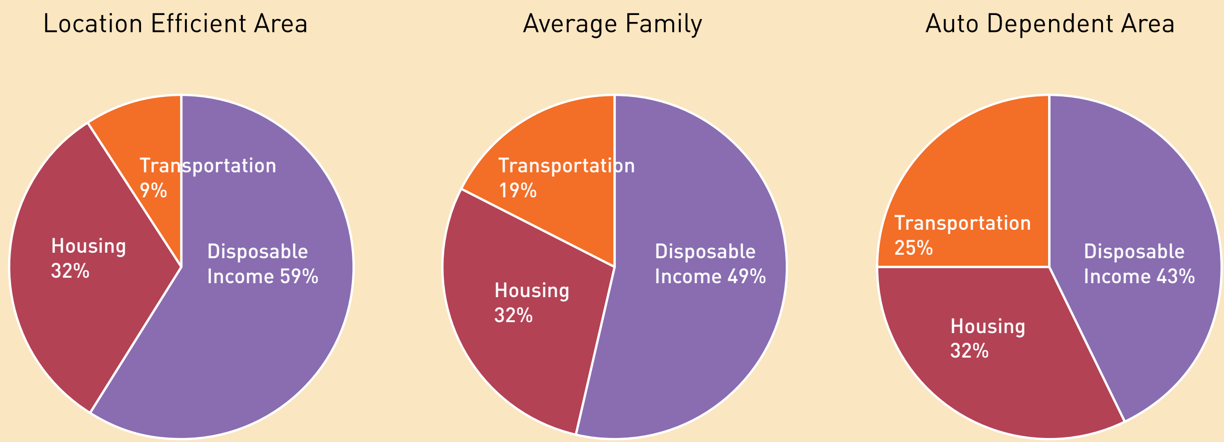
Economy

Not only does supporting active modes of transportation improve our health, it also saves us money. Forbes Magazine reported that bicyclists in the United States saved an estimated $4.6 billion in automobile fuel and maintenance costs in 2012. The average annual cost of owning a bicycle is $308 compared to $8,220 for a car.[72] Walking is essentially a free mode of transportation.

Where people choose to live and how they choose to move around the region can have a big impact on their pocketbooks. The Federal Highway Administration reports that automobile dependent households spend 25% of their income on maintaining and fueling their car(s), while households located nearer to their work in mixed use communities (location efficient areas) spend an average of 9% of their income on transportation (see Figure 6).

The Department of Housing and Urban Development, in association with EPA and FHWA, has created a tool to assess the affordability of locations throughout the country. The tool is available at locationaffordability.info

Figure 6 – Typical Household Expenses by Residential Area Type



Source: Federal Highway Administration

By planning for communities that provide more travel options and a better mix of uses, household expenditures are shifted away from transportation into disposable income, which can be used for a variety of goods and services.

Closing & Future Work

With improved knowledge of how planning and development decisions impact CO_2 emissions and patterns found throughout the Atlanta region, planners, policy-makers and citizens can make more informed decisions for future growth. Communities with sustainability goals that include greenhouse gas mitigation should consider the key findings in this report when drawing up future changes to land use and transportation plans. CO_2 emissions should be included as an important component of any future planning work.

The Atlanta region continues to better understand climate change mitigation and adaptation strategies. This ensures our region is at the table in future national conversations about climate change.

There is still much more work to be done to prepare the Atlanta region for the anticipated impacts of climate change in the coming decades. While the debate continues in Congress on what, if anything, to do about the changing climate, the Atlanta region should continue to analyze its vulnerability to climate change and better understand potential greenhouse gas reduction and adaptation measures to ensure a resilient land use and transportation system in the future. By exploring these options now and gathering useful information, ARC can help inform future federal policy and prepare for the possibility of eventual national climate change action.

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Understanding
the regulatory environment of climate change and the
impact
of community design on greenhouse gas emissions.

Transportation, Planning, Land Use and Air Quality Conference White Paper

ARC
ATLANTA REGIONAL COMMISSION

Assessing Metropolitan Atlanta's CO2 Emissions from an Activity-Based Transportation Model and Household Electricity Usage

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ABSTRACT

Aggregate CO_2 emissions were assessed and statistical relationships were determined between neighborhood design characteristics and expected greenhouse gas emissions. Data were acquired for both estimated transportation and household energy use through the Atlanta Regional Commission's Activity-Based Transportation Model and from an aggregated energy use by zip code database. These data served as a foundation for estimating 2010 Carbon Dioxide (CO_2) emissions in a 19 county area of the Atlanta metropolitan region.

Significant positive correlations exist in the Atlanta region between CO_2 emissions and household size (both number of people and physical size), a neighborhood's share of single family housing and the distance from the city center. This analysis illustrates locations in the region with the lowest carbon footprint. Intown neighborhoods, suburbs with mixed use and multifamily development, areas with good access to transit and neighborhoods with close proximity to major expressways have the lowest per capita and per household CO_2 emissions in the Atlanta region.

INTRODUCTION

There are numerous publications that relate a range of household and travel variables to CO_2 emissions (Musti 2011, NETL 2009, O'Neill 2002). This study focuses on combining key US Census household characteristics from a literature review and travel demand model output to produce Atlanta specific results. These results are displayed cartographically and through statistics to illuminate areas in the region that produce different levels of CO_2 emissions as well as to explain why these patterns may exist.

A primary goal of this study is to quantify CO_2 emissions. Quantifying greenhouse gas emissions is an important step in identifying potential strategies for mitigating global climate change that could be considered by planners and policymakers. By developing tools and methodologies to determine emissions at a local level, planners are able to achieve two key goals. First, planners can quantify the influence that design or neighborhood characteristics have on CO_2 emissions. After understanding which characteristics lead to increased emissions, planners can inform future public policy decisions. Second, planners are able to better understand the spatial characteristics of CO_2 emissions.

METHODOLOGY

The analysis undertaken by the Atlanta Regional Commission (ARC) sought to understand two primary sources of CO_2 emissions: residential household electricity use and personal transportation by automobile for the year 2010. Combined, these two sources account for approximately 60% of US greenhouse gas emissions (Environmental Protection Agency (EPA) 2013). The analysis was divided into two separate components using separate datasets. The results were summed to create a composite value of CO_2 emissions per person and per household.

Residential CO_2 Emissions

Southern Company, Georgia Power's electric holding company, provided annual household residential energy use in kilowatt-hours (kWh) for the year 2010 by 178 zip codes for a 19 county area of the Atlanta region. This database included the number of households within each of the 178 zip codes. Of the approximately 2 million households in the 19 county area Southern Company billed 1.1 million premises. No data was received for households billed by another provider. Some group quarters are represented by a single bill. In some zip codes a small percentage of the total households were billed by Southern Company, and those zip codes were excluded from the analysis if the sample size was less than 100 households to maintain a margin of error of ≤ 10%. Of the sampled zip codes, 90% had enough billed households to provide a margin of error of ≤ 5%.

Data on natural gas usage was not acquired for this study, and will be a topic of future investigation to improve the accuracy of results. Therefore a portion of the CO_2 emissions associated with heating homes and water is not being accounted for in some portions of the region.

To assess which neighborhood characteristics impact CO_2 emissions, 2007-2011 American Community Survey census data for 948 census tracts were aggregated up to zip code level data using an ESRI GIS analysis and MySQL queries (US Census Bureau 2013). The final aggregated database provided zip code level data that related household energy use and key census statistics. Household energy use in kWh was converted to kilograms (kg) of CO_2 using the conversion factor 2.92263 kg/kWh (EPA 2012). This factor was developed by the EPA for the southeast subregion of the United States and includes assumptions on the ratio of coal, oil, natural gas and renewable energy as well as energy loss from the electrical grid.

Statistical software (STATA) was used to determine correlations between energy use and census data. Key variables expected to most impact CO_2 emissions from literature were included in a multivariate regression to determine standardized coefficient values to assess the importance of each variable in the Atlanta study area (Musti 2011, NETL 2009, O'Neill 2002).

Transportation CO_2 Emissions

ARC maintains an Activity-Based Transportation Model (ABM) that microsimulates daily travel of individuals in a 20 county area by approximately 2,000 separate traffic analysis zones (TAZ). Automobile CO_2 emissions were estimated for the year 2010 by a traveler's home TAZ. A CO_2 emission factor of 0.423kg/mile converted daily distance traveled to mass of CO_2 (US EPA 2011). EPA developed this emission factor by considering the average gasoline vehicle on the road in the United States in 2011. Multiplying daily CO_2 values by the Motor Vehicle Emission Simulator (MOVES) urban weekend adjustment factor (341.9809) annualized the average annual weekday emissions provided by the ABM.

This methodology ignores CO_2 emissions from transit. Calculating accurate transit CO_2 emissions rates to apply to the transit systems in metropolitan Atlanta was beyond the scope of this project. The ABM does not separate the distances of *drive-to-transit* trips into separate automobile and transit components. Transit ridership accounts for approximately 3% of regional distance traveled daily in the 20 county ABM domain. Since transit trips tend to be shorter than automobile trips, the median percent of total distance traveled by transit per TAZ in the Atlanta region is 1%. Moreover, transit emissions are assumed to be lower than personal automobile travel per mile. As a result, this study may be only slightly underestimating transportation-related CO_2 emissions in areas that have high transit ridership.

Total CO_2 Emissions

Household electricity-derived emissions across a zip code were assumed to be equal. This assumption allows the analysis resolution to be set to the finer TAZ geography by applying a constant emission per household at the zip code level. Maps and data are presented on a per household and per person level.

RESULTS

Residential CO_2 Emissions

Correlation between household energy use and key census variables is outlined in Table 1. Only statistically significant ($p \leq 0.05$) variables are included.

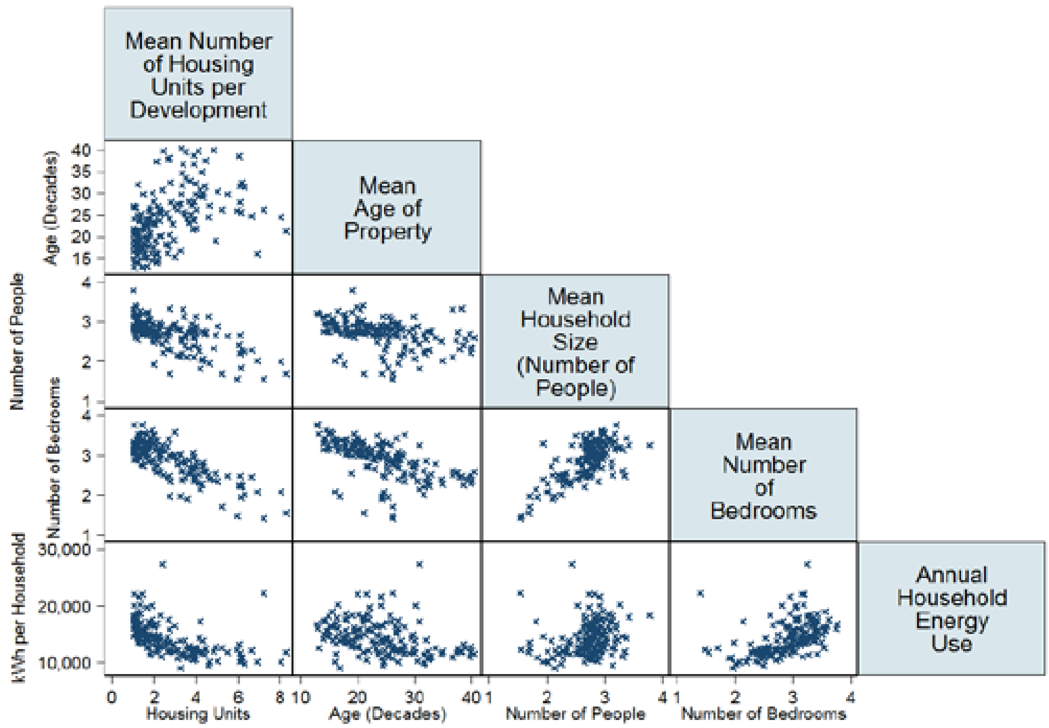
Table 1. Correlations between Household Energy Use and Census Data

Variable	Correlation Coefficient
Mean Number of Housing Units per Development	-0.5498
Mean Number of Bedrooms	0.4847
Mean Age of Property	-0.3817
Mean Household Size (Number of People in Household)	0.2725
Median Number of Rooms per Household	0.3997

Variables that relate to the size of the house (mean number of bedrooms and mean number of rooms), the number of people living in a household, the age of the property and the prevalence of multi-family development (mean number of housing units per development) all impact household energy use. The relationship between these variables can be very complex, especially when measured across an entire zip code. Some variables, like the age of a property, can be collinear with household size, since older homes are often smaller than newer homes (Census 2011). The median number of rooms per household was found to have a collinearity condition index of 23.73 with respect to the mean number of bedrooms and was dropped from the analysis.

Figure 1 illustrates example relationships between household energy use and the key assessed variables. The figure includes intervariable relationships. There is a wide range of variability between zip codes. The Atlanta region is not homogenous in its design; a large range of housing styles, sizes, ages, *etc.* are all located within relatively close proximity.

Figure 1. Zip Code Geography Census Data Correlation Matrix



Several combinations of census household characteristic variables were factored into a regression analysis. Variables were selected based on the strength of correlation with energy use per household and literature. Prior to running the regression the variables were normalized. Table 2 outlines the findings of the regression analysis. The R-squared term for the model is 0.5456.

Table 2. Emissions per Household vs. Census Characteristics Regression Output

Variable	t-value	p-value	Beta
Mean Household Size	-2.00	0.047	-0.1951
Mean Age of Household	1.48	0.142	0.1141
Mean Number of Housing Units per Development	-2.52	0.013	-0.2592
Mean Number of Bedrooms	4.93	0.000	0.7687
Median Household Value	3.67	0.000	0.5700
Percent Electric Power Heating	7.52	0.000	0.4698

A term for the percent of households using electricity to heat their homes was found to be an important variable with one of the highest beta standardized coefficients. This variable, however, is not important from a perspective of design characteristics to inform planning or personal decisions making. Most heating in metropolitan Atlanta that does not come from electricity comes from natural gas which also produces CO_2 emissions. The mean household size in the model is at the threshold of significance, most likely due to the large variance in electricity use per household with a small variance in household size. Anecdotally, household size should be an important determinant. The median value of a household (*i.e.* the cost of housing stock) is significant, as a proxy for both household size, income and age which literature suggests are important factors in total electricity use (Musti 2011, O'Neill 2002). Mean age of household was found to be insignificant by this model. Overall, the variables that relate to the size of the household and number of households per development carry the highest standardized coefficients.

Electricity usage was converted to annual metric tons of CO_2 per household and per person by zip code in Figures 2 and 3. Because each additional member of a household does not increase electricity usage in a one-to-one relationship, CO_2 emission efficiencies are gained by living in a household with more people. Households in the suburbs surrounding the I-285 perimeter expressway and in southwest Atlanta have a larger share of children, which is reflected in lower per capita CO_2 emissions. On a per household level, however, areas closer to the center of the region tend to have lower emissions, due to there being fewer people per household, a higher incidence of multi-family housing and smaller total house size.

Figure 2. Annual Residential CO_2 Emissions per Person by Zip Code in 2010

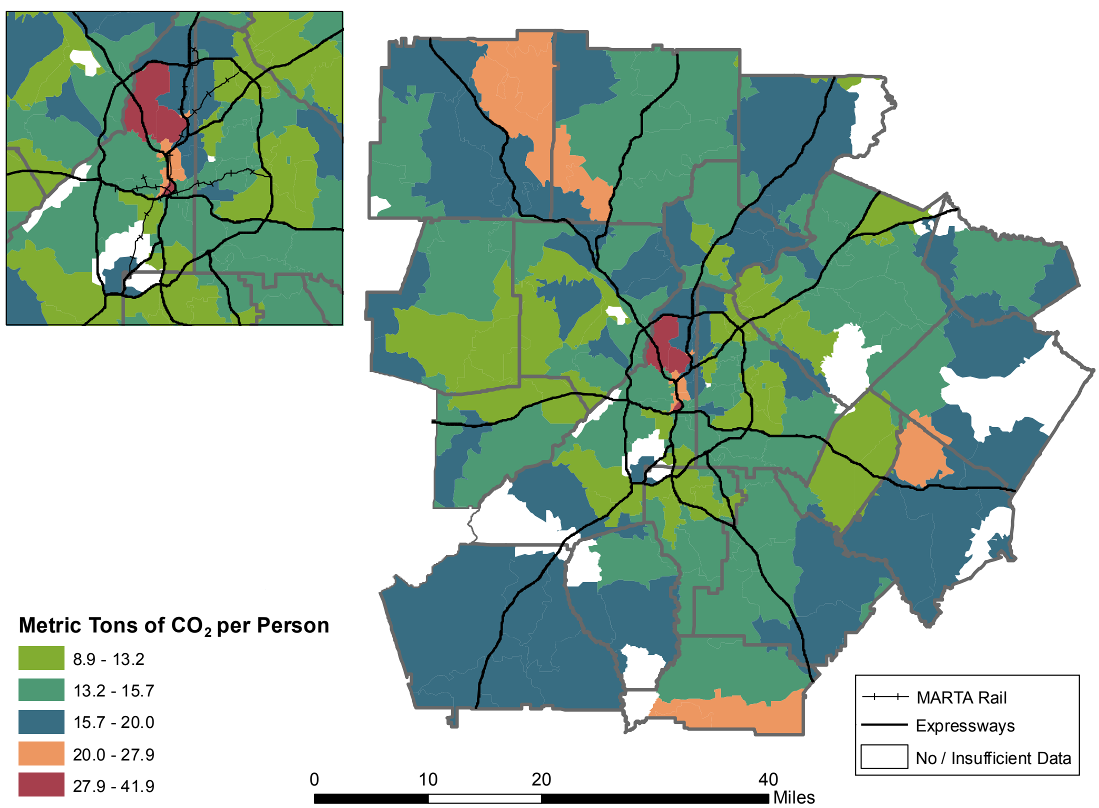
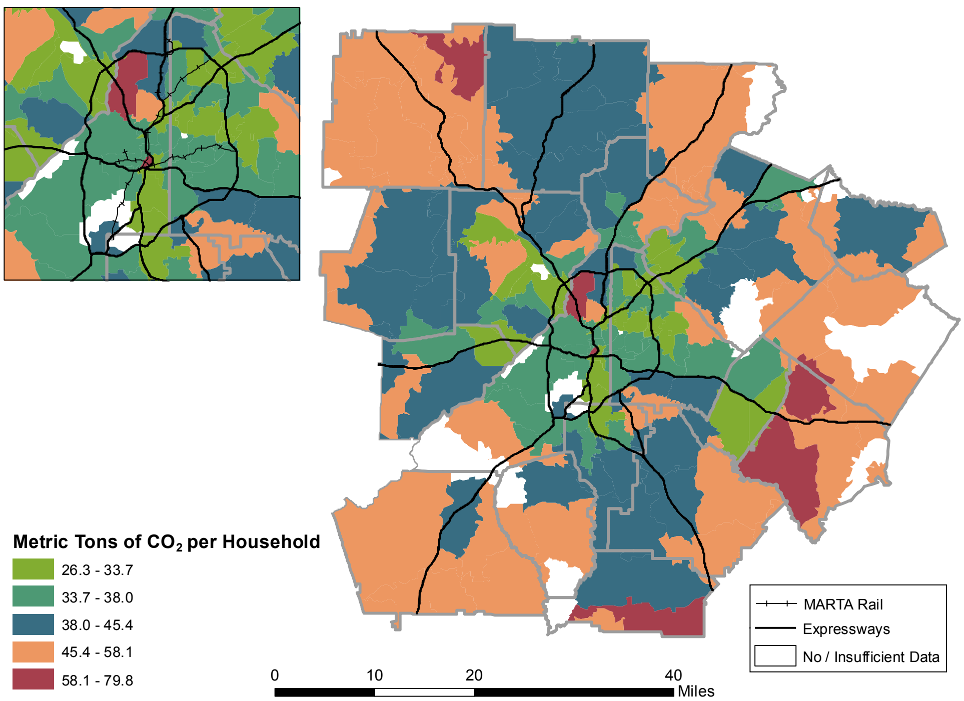


Figure 3. Annual Residential CO_2 Emissions per Household by Zip Code in 2010



Transportation CO_2 Emissions

In this study, CO_2 emissions from transportation were assumed to be only a factor of the distance traveled aggregated to an individual's home TAZ. The spatial pattern of emissions on a per person or per household basis is very similar in the Atlanta region. The total transportation CO_2 emissions per household minimize in the center of the region, in regional town centers, near MARTA heavy rail corridors and along major expressways (see Figure 4, below). These areas provide the highest connectivity and access to employment and retail opportunities in the Atlanta region. Minimized transportation CO_2 emissions are primarily a function of access to trip attractors.

Aggregated CO2 Emissions

Total CO_2 emissions are calculated by summing residential and automobile CO_2 emissions. Transportation's share of CO_2 emissions per household ranges from near 0% to 36% (Figure 5). Areas closer to the center of the region, regional activity centers, and regional town centers tend to have a lower portion of their total carbon footprint from transportation. The weighted mean contribution of personal transportation to the total regional CO_2 emission is 15% per household.

Figure 4. Annual Automobile CO_2 Emissions per Household in 2010

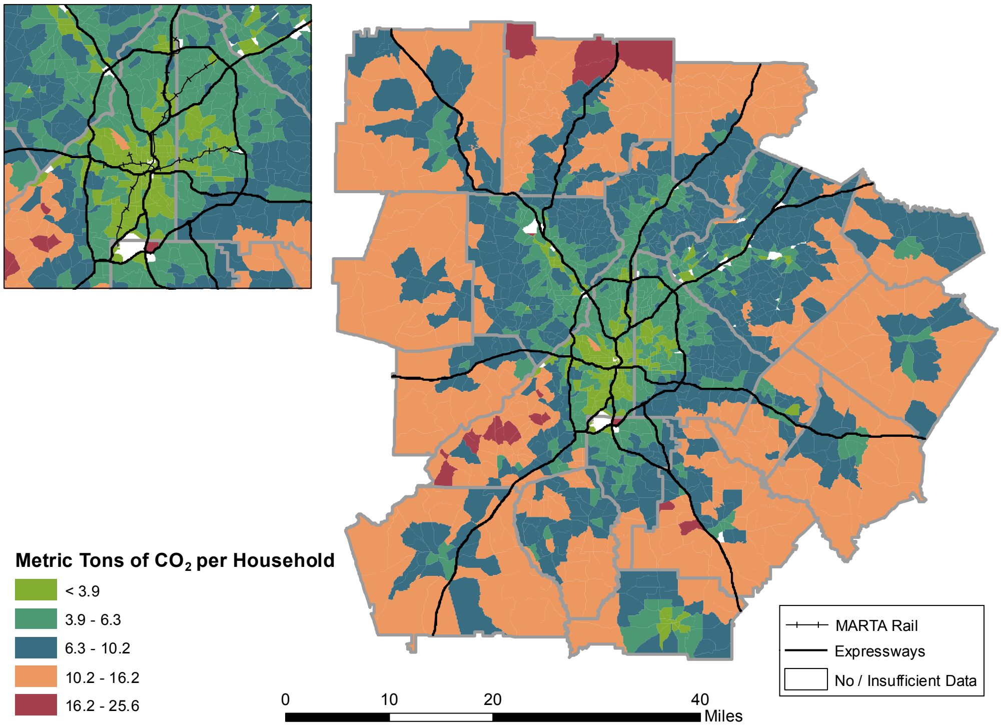
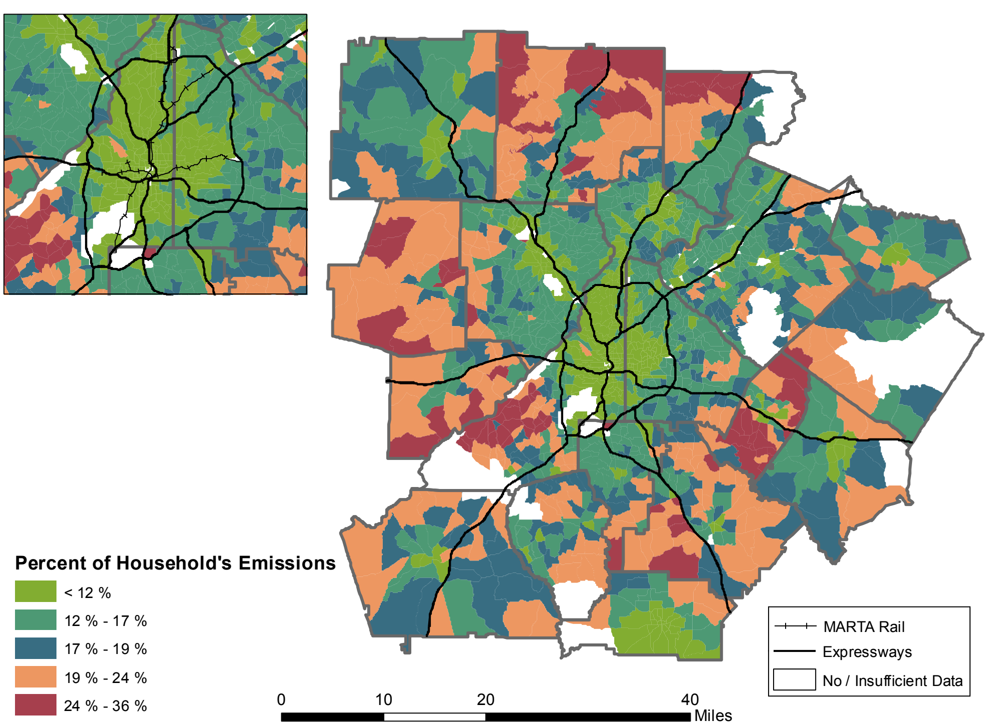


Figure 5. Percent of Household CO_2 Emissions from Automobile Usage in 2010



Figures 6 and 7 illustrate total per household and per capita CO_2 emissions. The spatial pattern of emissions is strongly driven by household emissions. Again, per capita emissions are driven down by the presence of multi-person households in suburban areas around the I-285 perimeter expressway and in southwest Atlanta. Some per capita benefit from multi-person households is eroded in the outer areas of the region due to an increase in transportation emissions. On a per household basis, intown and nearby suburban neighborhoods produce the least emissions.

The World Bank reports the 2008-2012 per capita CO_2 emission in the United States at 17.3 metric tons per person (World Bank 2013). This value estimates emissions from all types of activities, not just residential and automobile usage. The methodology utilized in this paper produces a comparable result. Atlanta regional CO_2 emissions were found to be 17.9 metric tons per person. Some of the difference in values is explained by the fact that the Atlanta region has larger than average commute emissions and the region is less industrialized than other locations in the nation. In addition, the southeastern United States has one of the lowest shares of renewable energy electricity generation, resulting in additional residential emissions from power generation.

Figure 6. Total Annual CO_2 Emissions per Person

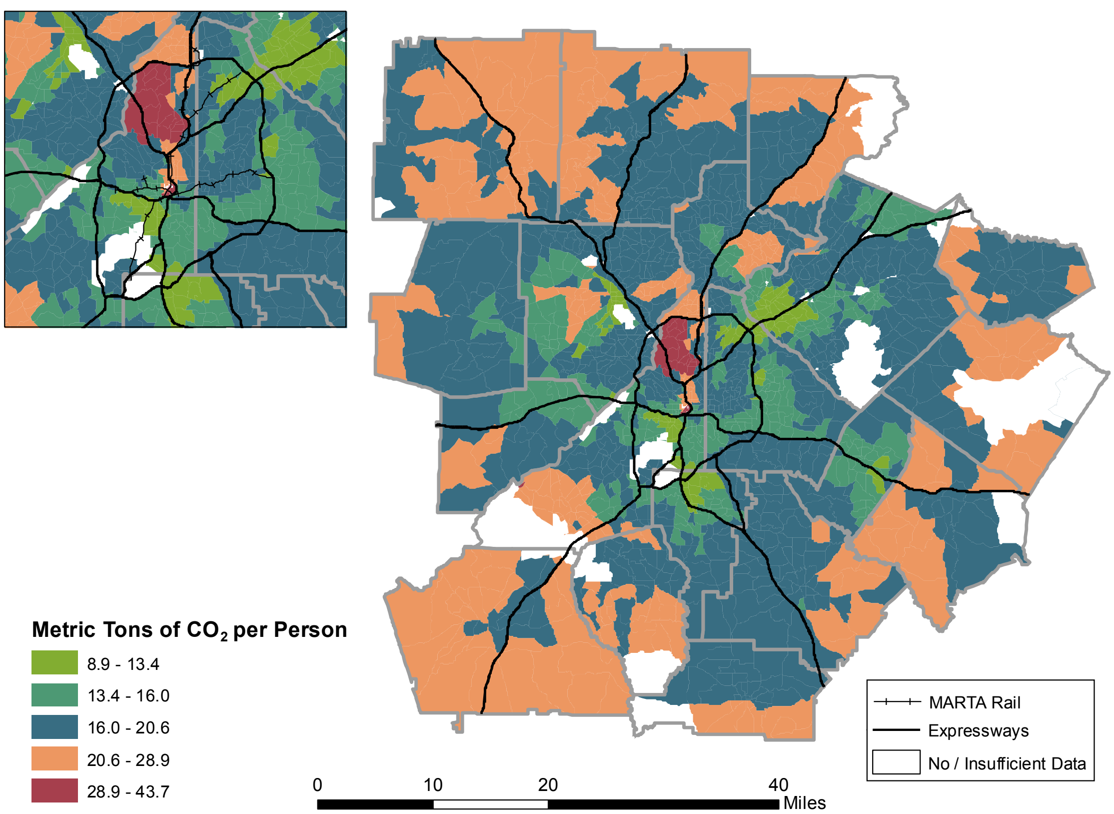
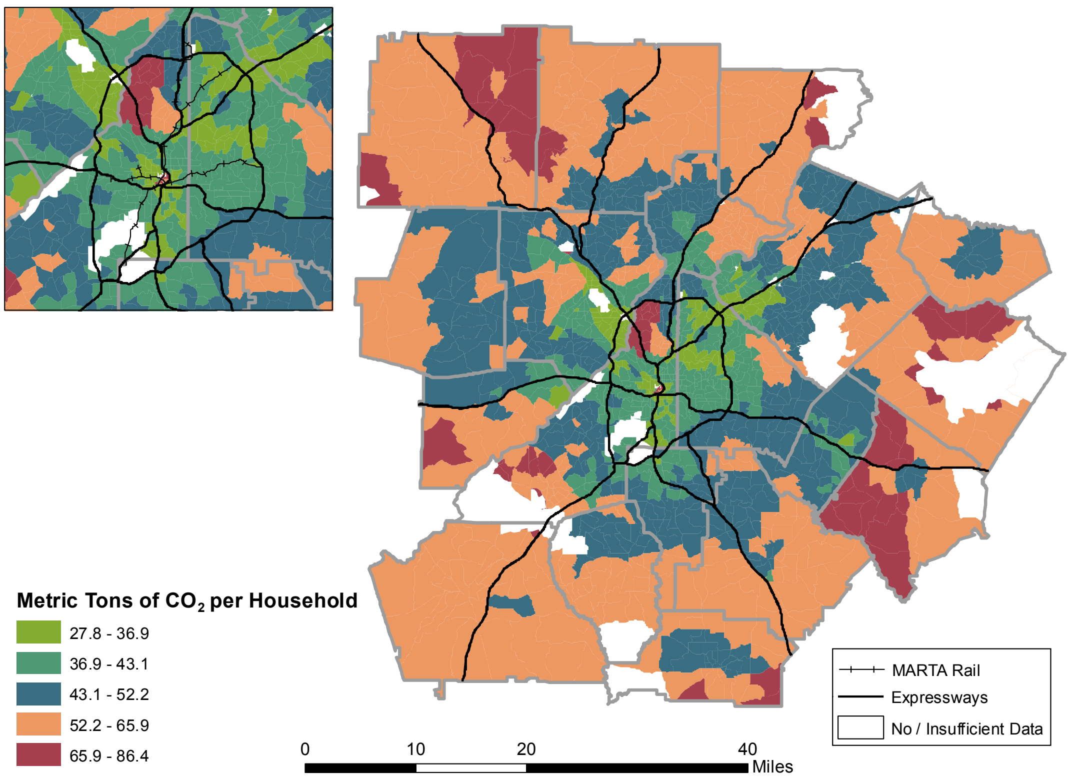


Figure 7. Total Annual CO_2 Emissions per Household



CONCLUSION

This analysis confirms that CO_2 emissions can be correlated with residential and transportation characteristics as well as proximity to activity centers and major travel attractors, even with the caveats associated with the data and techniques utilized.

Key findings from this study include: (1) a community's share of multifamily housing impacts CO_2 emissions. The mean number of housing units per development exhibited the largest negative correlation with emissions per household. (2) Mixed use communities reduce the need to drive. These relationships should be mathematically evaluated in a future study. (3) Living near major activity and employment centers as well as near historic town centers reduces CO_2 emissions from transportation by encouraging a range of travel modes and shorter automobile driving distances. (4) Physically smaller households correlate to less energy use per household. Larger household spaces require more energy to heat and cool. (5) Older homes are often smaller than their modern counterparts and are located closer to major activity centers, but there is an unclear relationship between age of property and CO_2 emissions. Part of this uncertainty could be due to energy inefficiency issues with older properties. Weatherizing households could help to reduce emissions and bring older properties' emissions in line with newer properties of similar size and household makeup. Further research is needed to evaluate this relationship.

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APPENDIX 2

Understanding

the regulatory environment of climate change and the

impact

of community design on greenhouse gas emissions.

Statistics & Relationships

ATLANTA REGIONAL COMMISSION

Overview

This appendix provides a more detailed look at some of the statistical relationships between the key indicators and CO_2 emissions. It is broken down into sections on the correlations, means, figures and maps that help explain the results presented in the main body of the report.

Correlations

Table 1 illustrates the correlation factors between key indicators and household transportation CO_2 emissions (main report Table 2). The number of samples is 1,856 traffic analysis zones. The significance level is below 0.03 ($p<0.03$) for all correlations.

Table 1 – Key Indicators and their Correlation to Household Transportation CO_2 Emissions

Key Indicator	Description	Correlation
Total Employment	Total employment in the Traffic Analysis Zone (TAZ)	-0.364
Employment Density	Total employment in the TAZ per unit area	-0.233
Population Density	Total population in the TAZ per unit area	-0.428
Housing Density	Total households in the TAZ per unit area	-0.395
Bike Percent	Relative distance of bike trips to total trip length by residents of the TAZ	-0.415
Drive Alone Percent	Relative distance of single-occupant vehicle trips to total trip length by residents of the TAZ	0.527
Walk Percent	Relative distance of walk trips to total trip length by residents of the TAZ	-0.518
Transit Percent	Relative distance of transit trips to total trip length by residents of the TAZ	-0.515
Jobs-Housing Balance	Ratio of the number of jobs to housing units in the TAZ	-0.141
ARC Multimodal Access Index	Measure of how many transportation options to employment exist in a community	-0.635
ARC Walkability Index	Measure of the walkability of a community	-0.309
Distance to Regional Activity Centers	The proximity of a TAZ to major employment centers	0.444
Distance to GRTA Express Park & Rides	The proximity of a TAZ to GRTA park and rides	0.049

Table 2 displays similar information for the relationship of household CO_2 emissions and key census data at the zip code level. The number of samples is 178 zip codes. The significance level is below 0.05 ($p<0.05$) for all correlations.

Table 2 – Correlations between Residential Electricity Household CO_2 Emissions and Census Data

Key Indicator	Description	Correlation
Mean Number of Housing Units per Development	Measure to assess how much multi-family housing is present in community	-0.550
Mean Number of Bedrooms	Relates to size of residence; collinear with median number of rooms per household	0.485
Mean Age of Property	Age of residence; collinear with household size	-0.382
Mean Household Size	Number of people per household	0.273
Median Number of Rooms per Household	Relates to size of residence; collinear with mean number of bedrooms	0.400

Means

Table 3, below, looks at the relationships reported in Table 3 of the main report. Mean transportation and total CO_2 emissions are reported (per household and per person) based on the presence of indicators directly located within a community. The number of samples sum for each category as outlined in Table 4. The margin of error for the transit stations indicator is approximately 17%. The other indicators are all less than 10%.

Table 3 – Neighborhood Indicators and their Mean CO_2 Emissions

Indicator	Indicator Present in Community				Indicator Absent in Community			
	Transportation CO_2		Total CO_2		Transportation CO_2		Total CO_2	
	/Household	/Person	/Household	/Person	/Household	/Person	/Household	/Person
Transit Station	3,007 kg	1,466 kg	40,754 kg	19,177 kg	7,382 kg	2,745 kg	49,074 kg	18,331 kg
LCI Community	3,842 kg	1,684 kg	43,147 kg	19,032 kg	7,797 kg	2,869 kg	49,749 kg	18,248 kg
2013 WalkUPs	2,780 kg	1,456 kg	43,543 kg	22,149 kg	7,631 kg	2,813 kg	49,316 kg	18,074 kg

Table 4 – Neighborhood Indicators and their Mean CO_2 Emissions Sample Sizes

Indicator	Sample Size if Indicator Present in Community	Sample Size if Indicator Absent in Community
Transit Station	32	1,824
LCI Community	230	1,626
2013 WalkUPs	124	1,732

Figures

The following figures chart the relationship between total household automobile CO_2 emissions and several key indicator variables to help visualize the relationships. The number of samples for all figures is 1,856 Traffic Analysis Zones.

Figure 1 – Housing Density

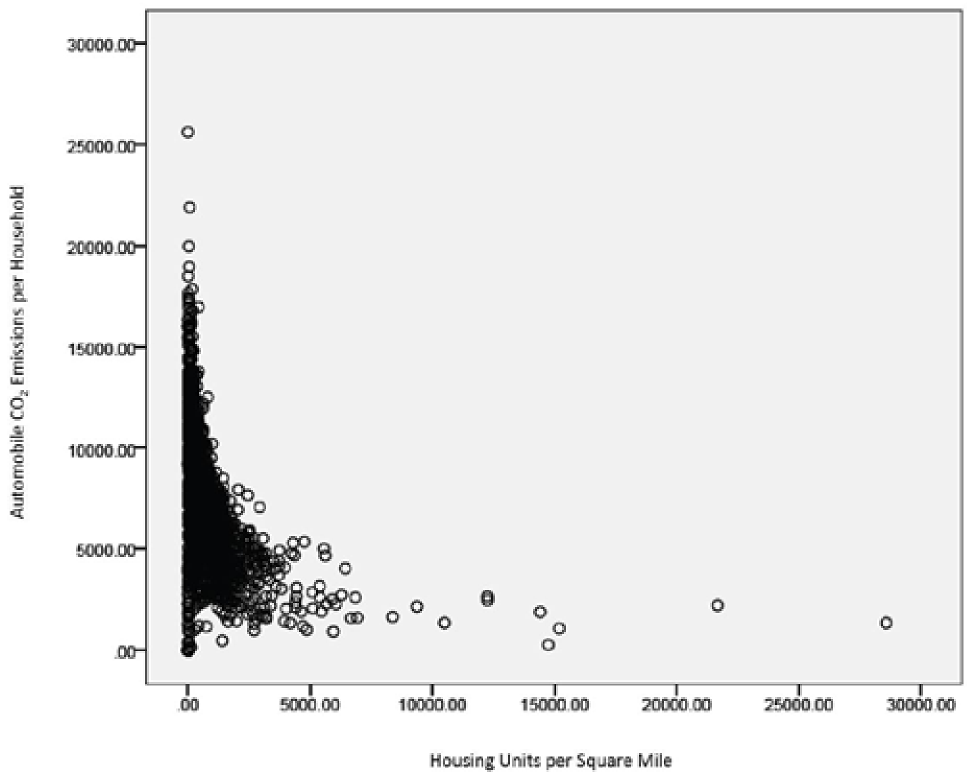


Figure 2 – Multimodal Accessibility Index

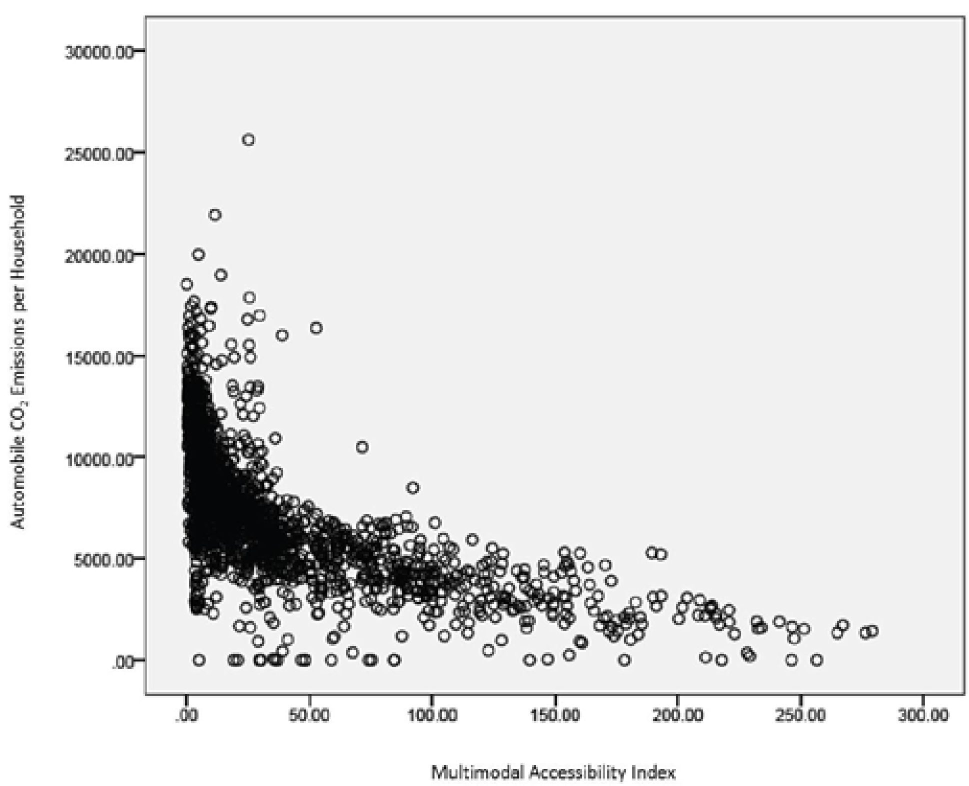


Figure 3 – ARC Walkability Index

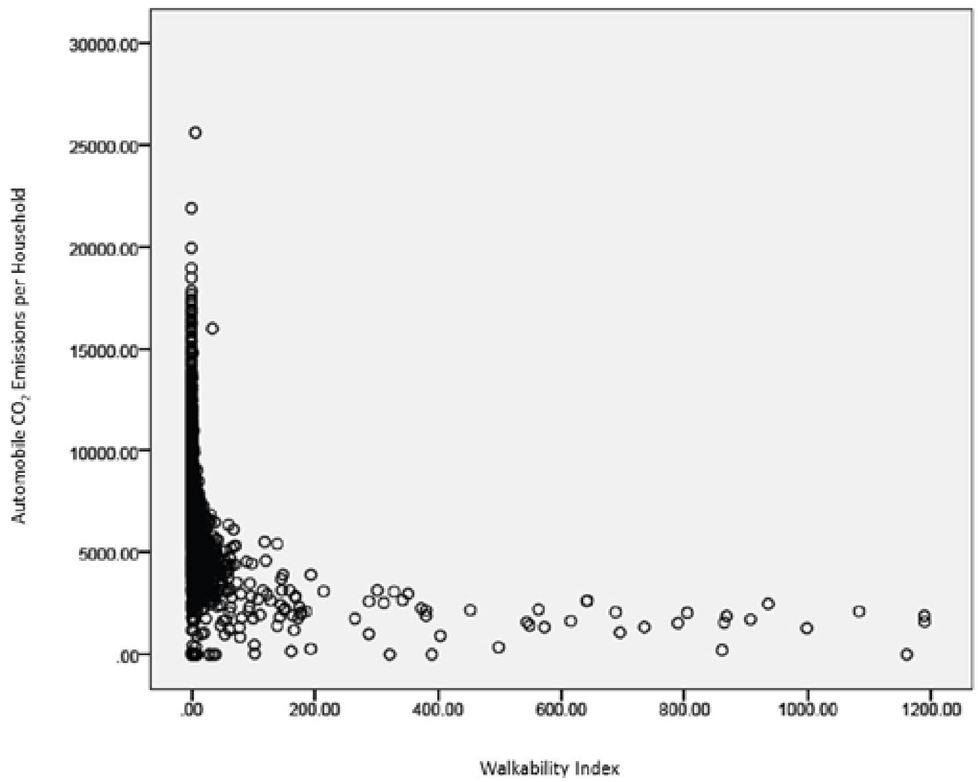


Figure 4 – Distance to Nearest Activity Center

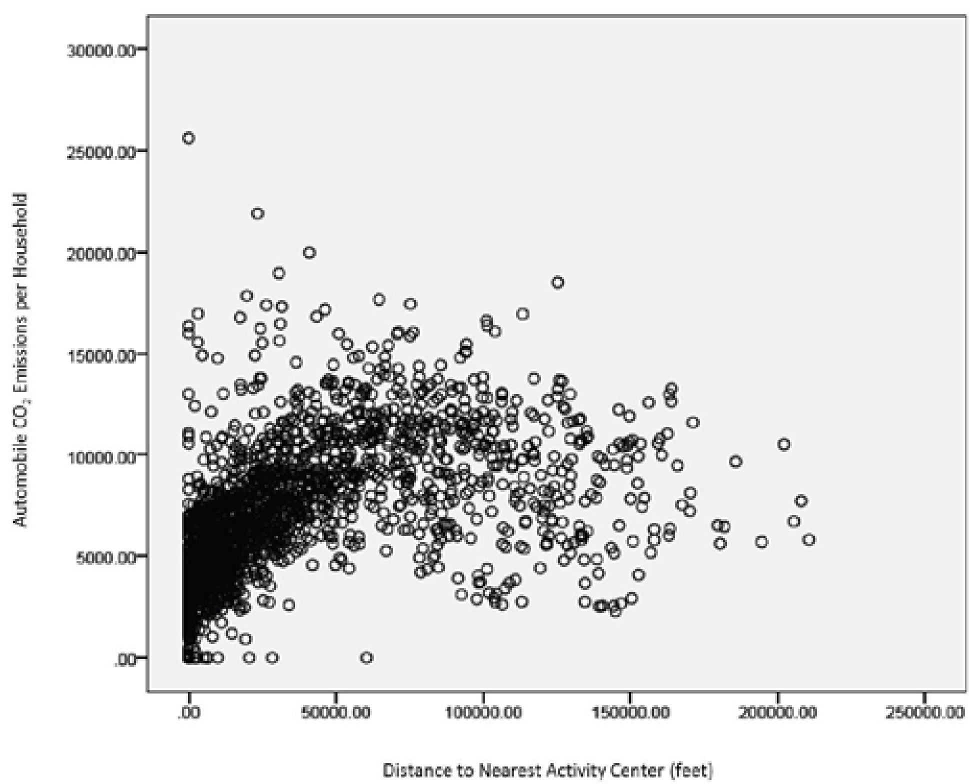


Figure 5 – Distance to Nearest GRTA Express Park & Ride Lot

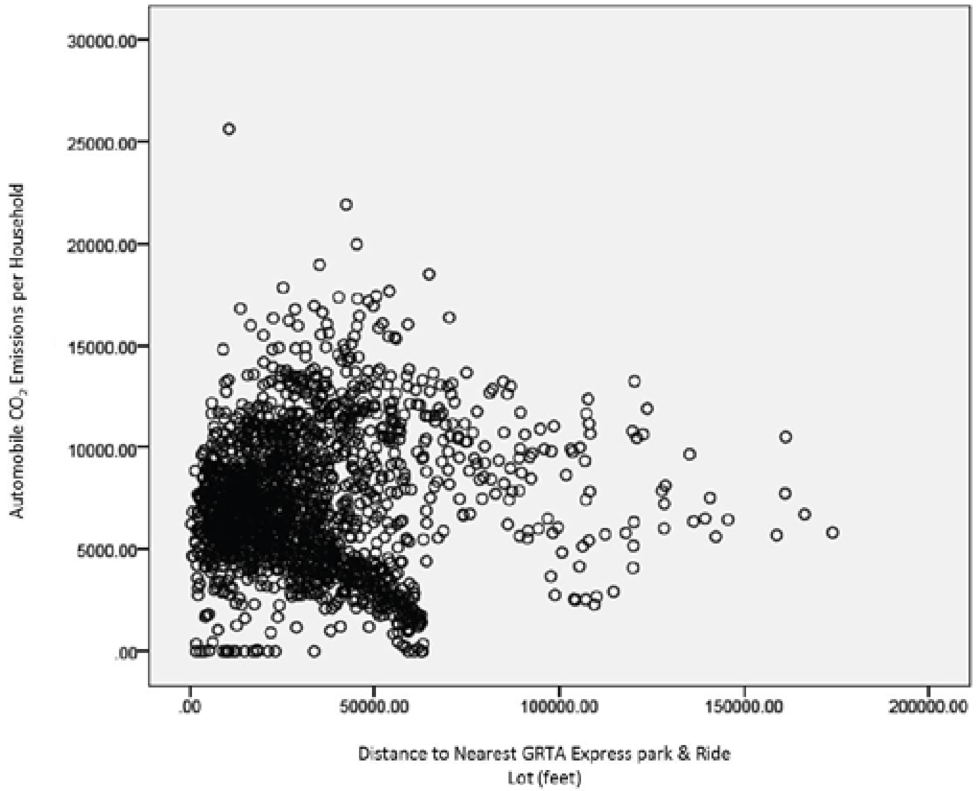


Figure 6 – Percent of Drive Alone Trip Distance

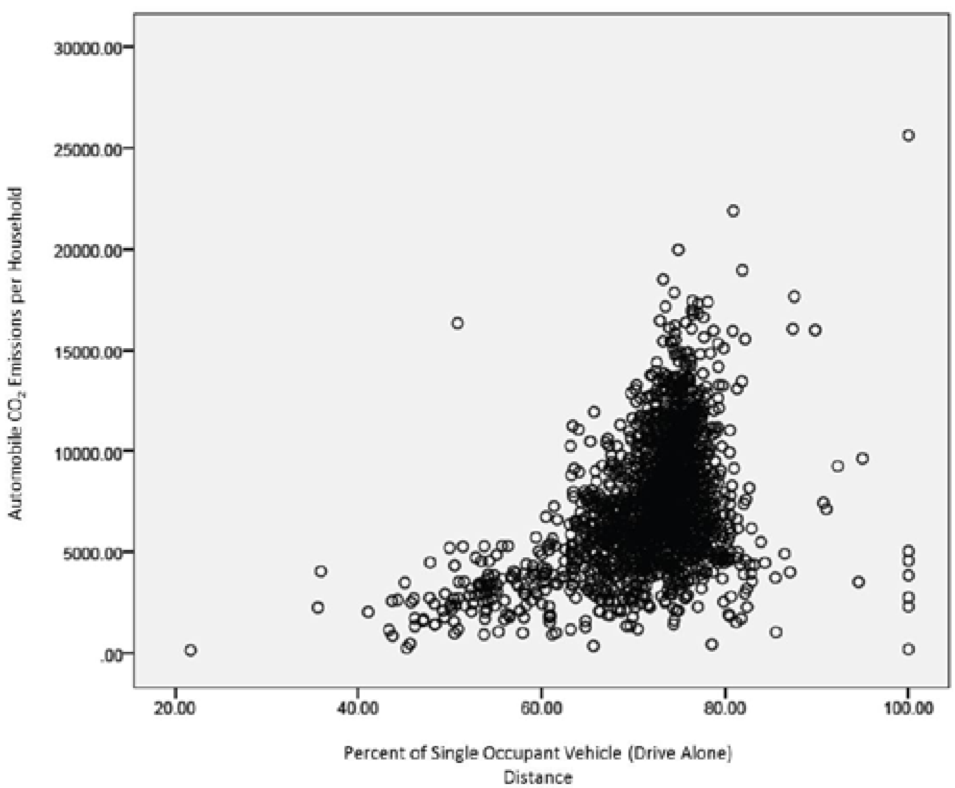


Figure 7 – Percent of Bike Trip Distance

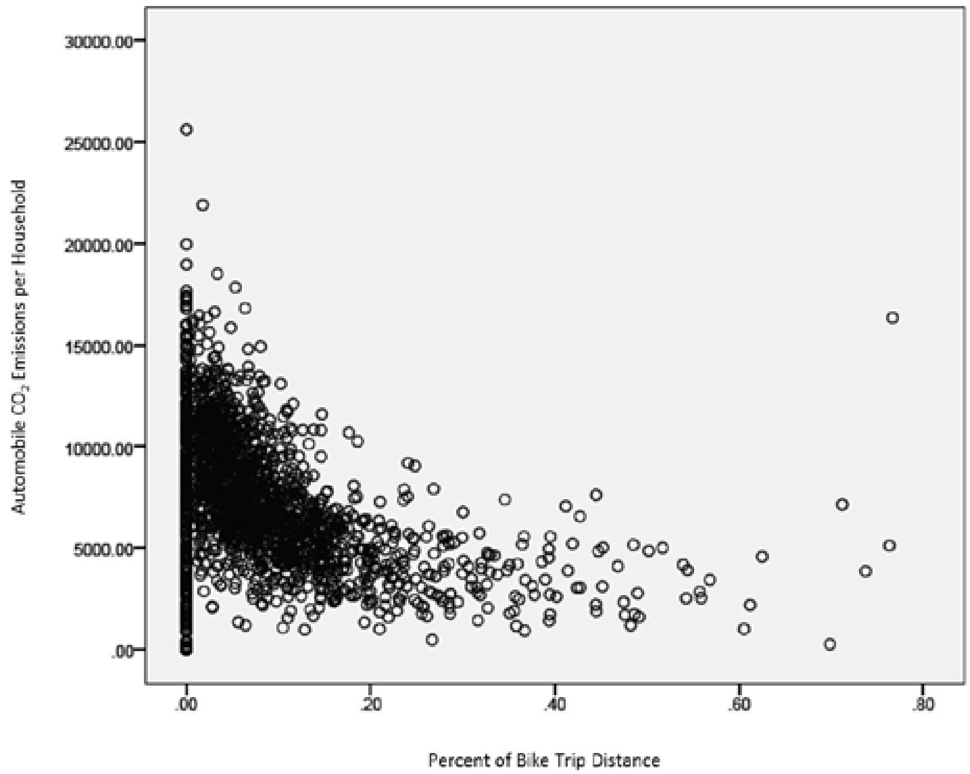


Figure 8 – Percent of Walking Trip Distance

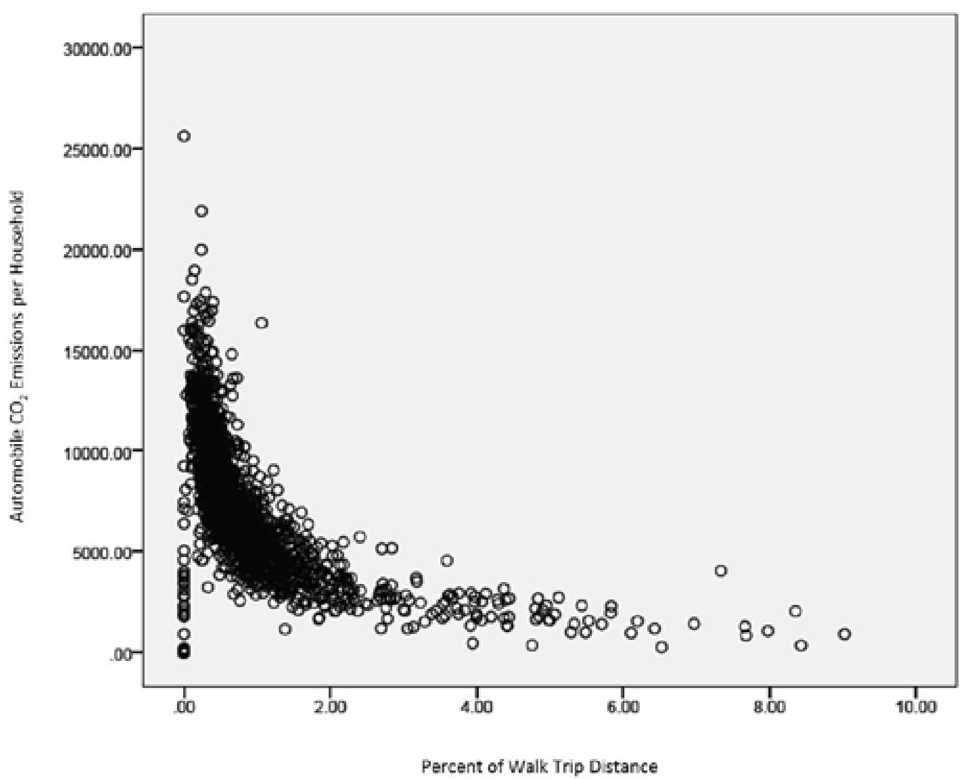
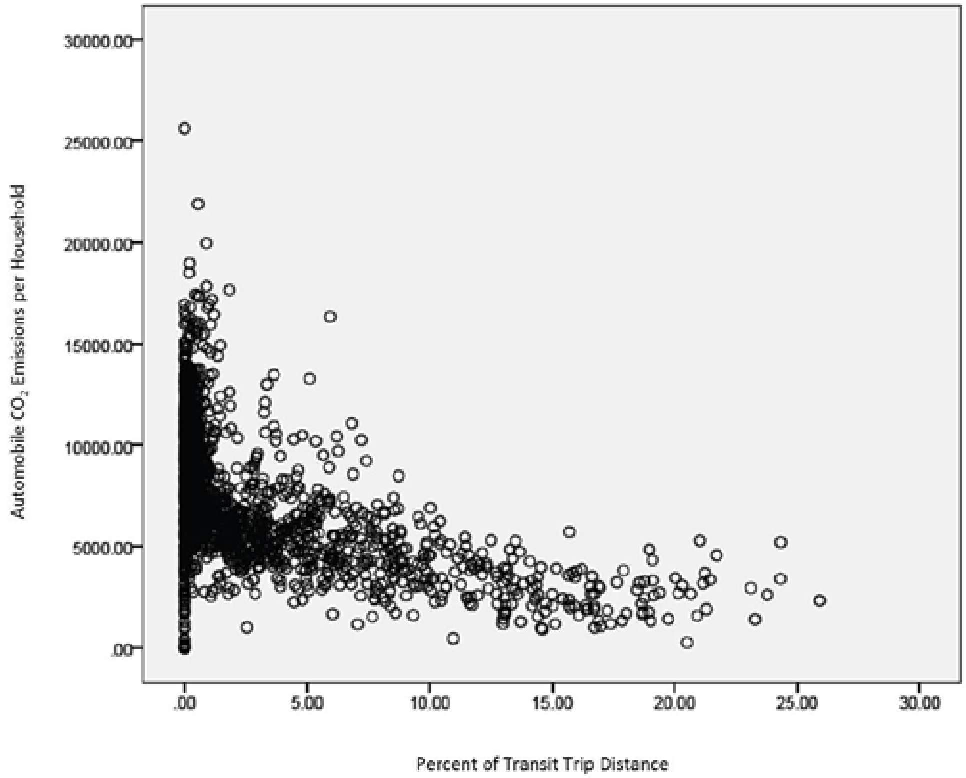


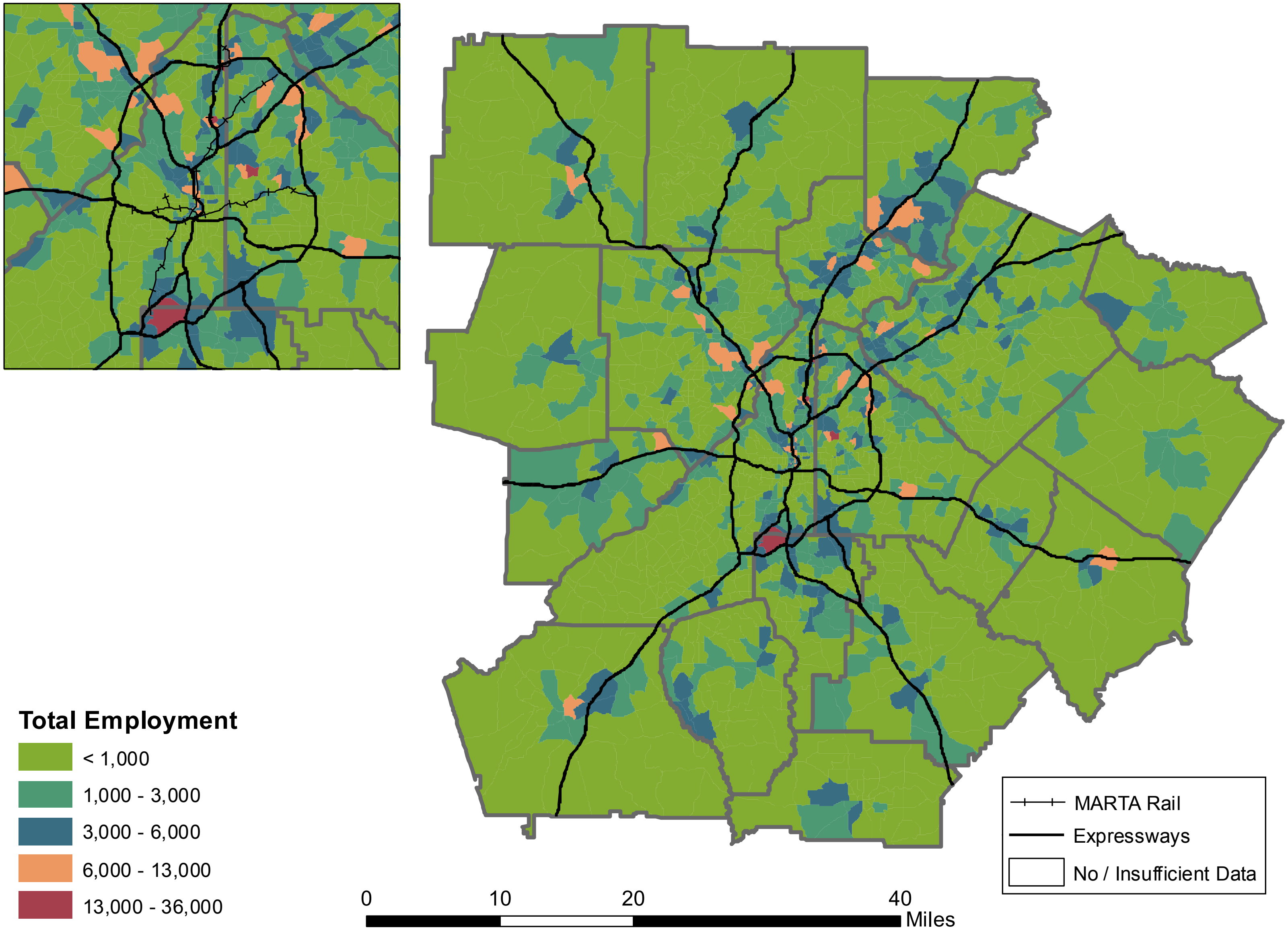
Figure 9 – Percent of Transit Trip Distance



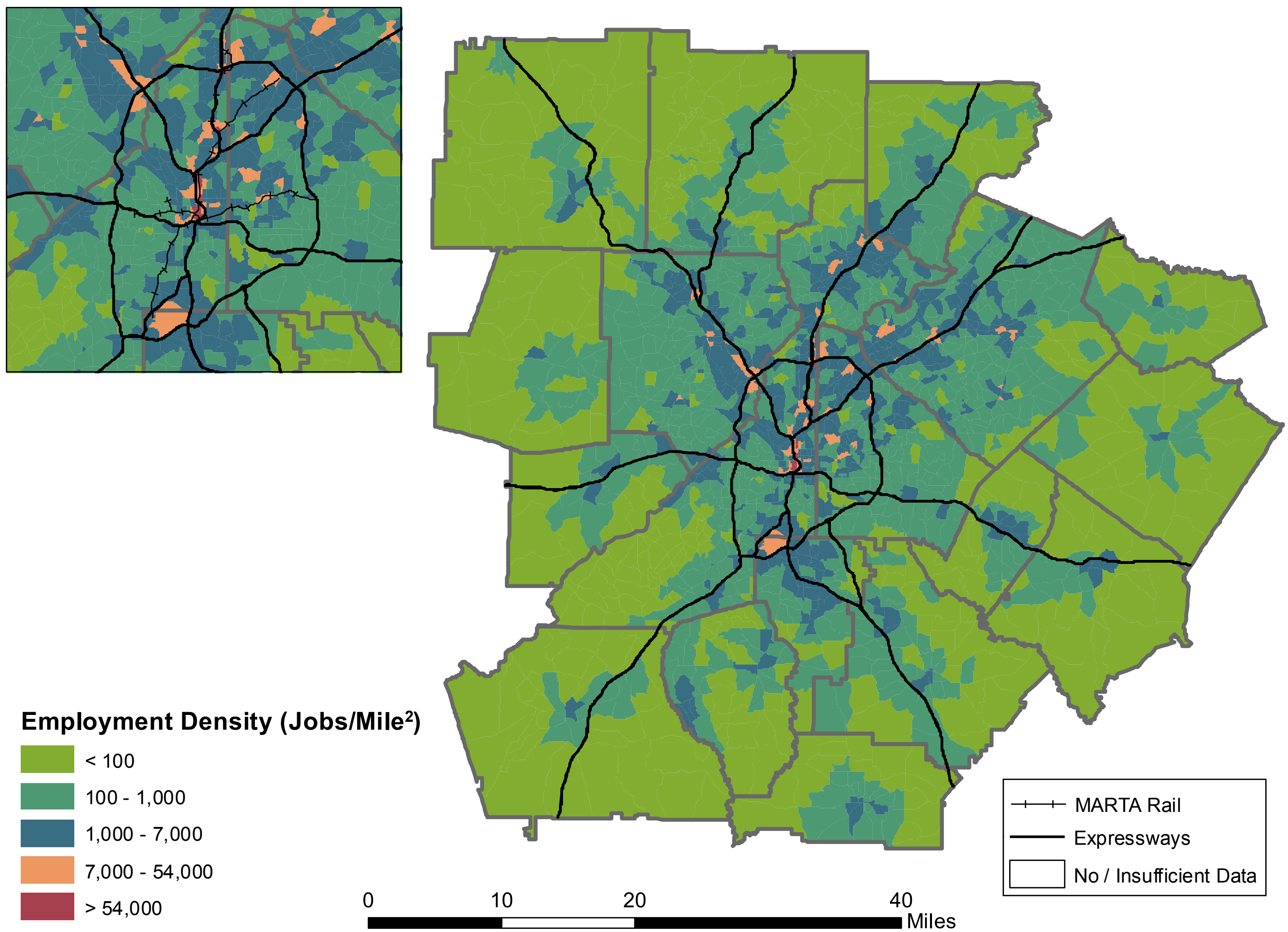
Maps

The following maps display the key indicators correlated to CO_2 emissions in the region. The maps can be visually compared to the residential, transportation and combined CO_2 emissions to get a sense for the statistical relationships evaluated in Tables 1 and 2 of this appendix, and in the main body of the report.

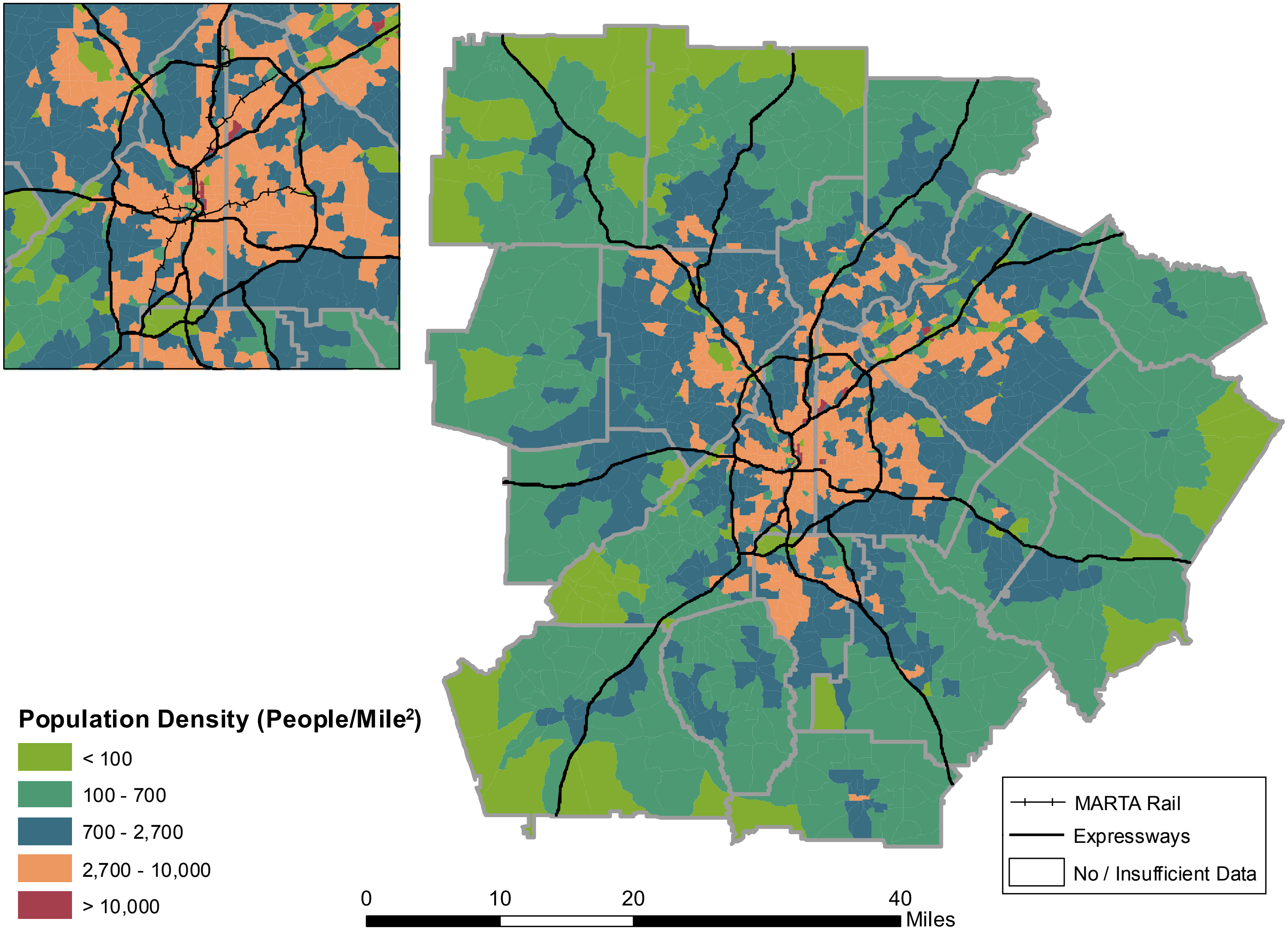
Map 1 – Total Employment by Traffic Analysis Zone



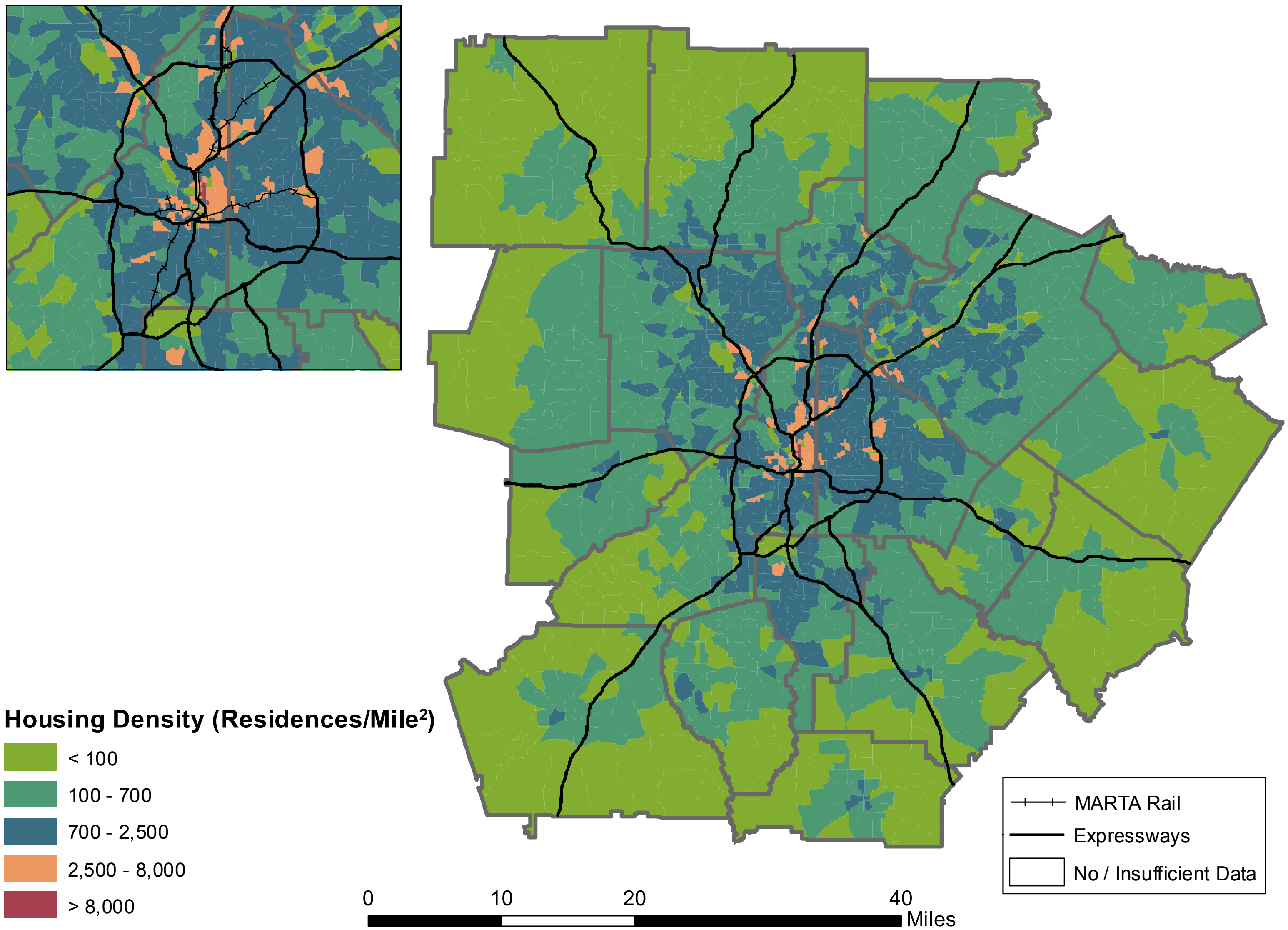
Map 2 – Total Employment Density by Traffic Analysis Zone



Map 3 – Total Population Density by Traffic Analysis Zone



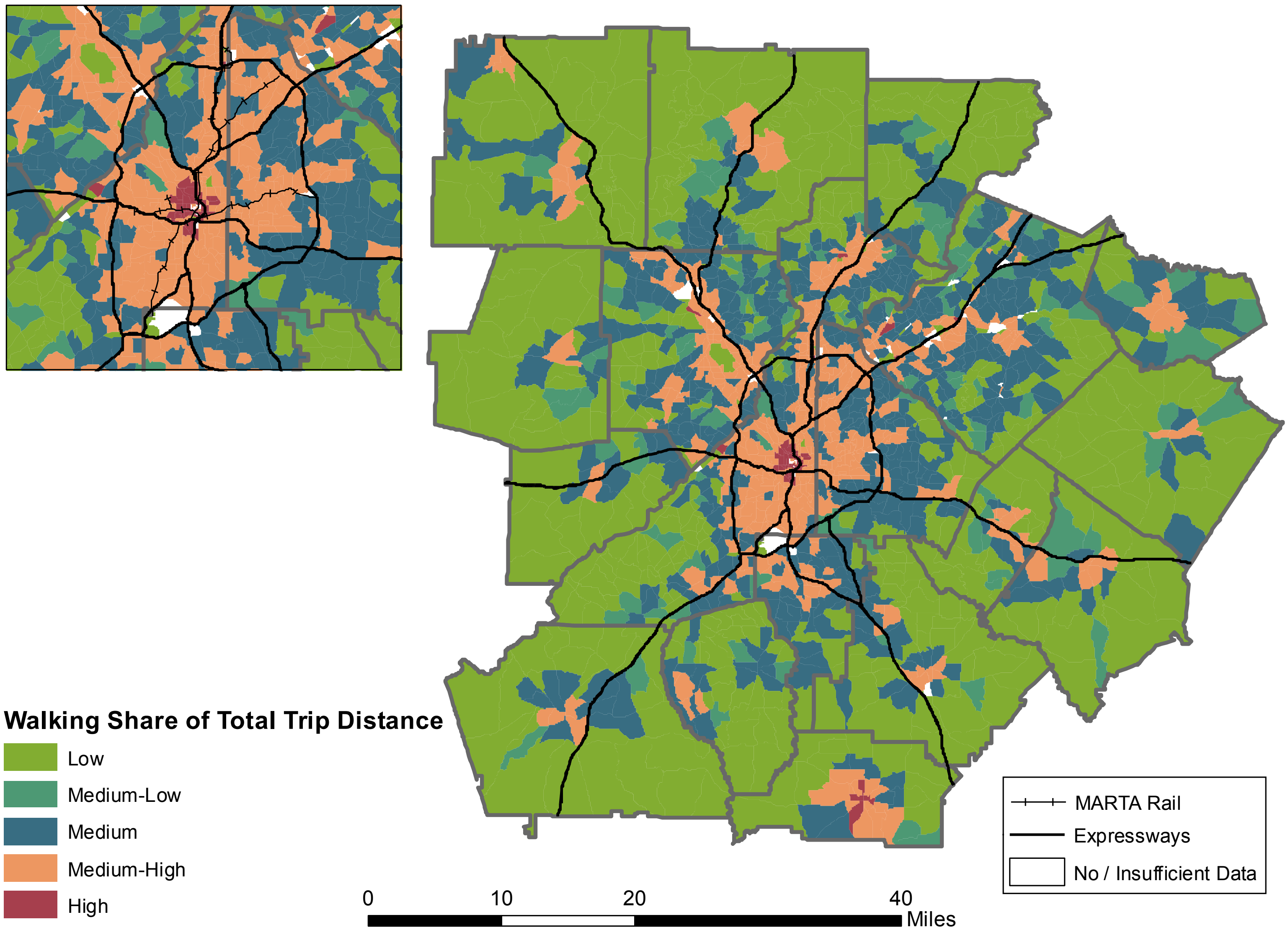
Map 4 – Total Housing Density by Traffic Analysis Zone



Map 5 – Bike Share of Total Trip Distance by Traffic Analysis Zone

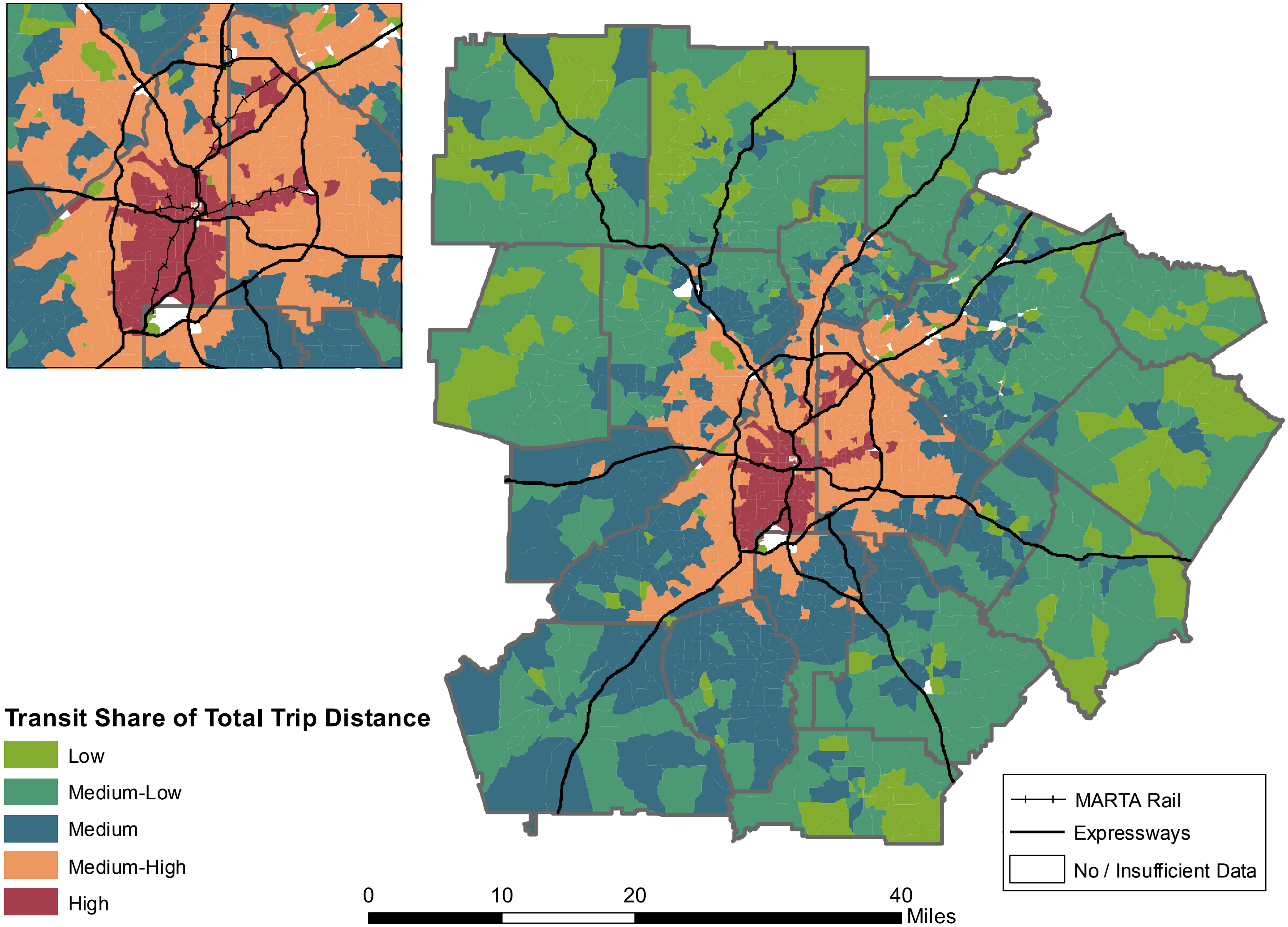
Note: bike trips represent a small portion of total trip distance in the Atlanta region. The index is relative.

Map 6 – Walk Share of Total Trip Distance by Traffic Analysis Zone



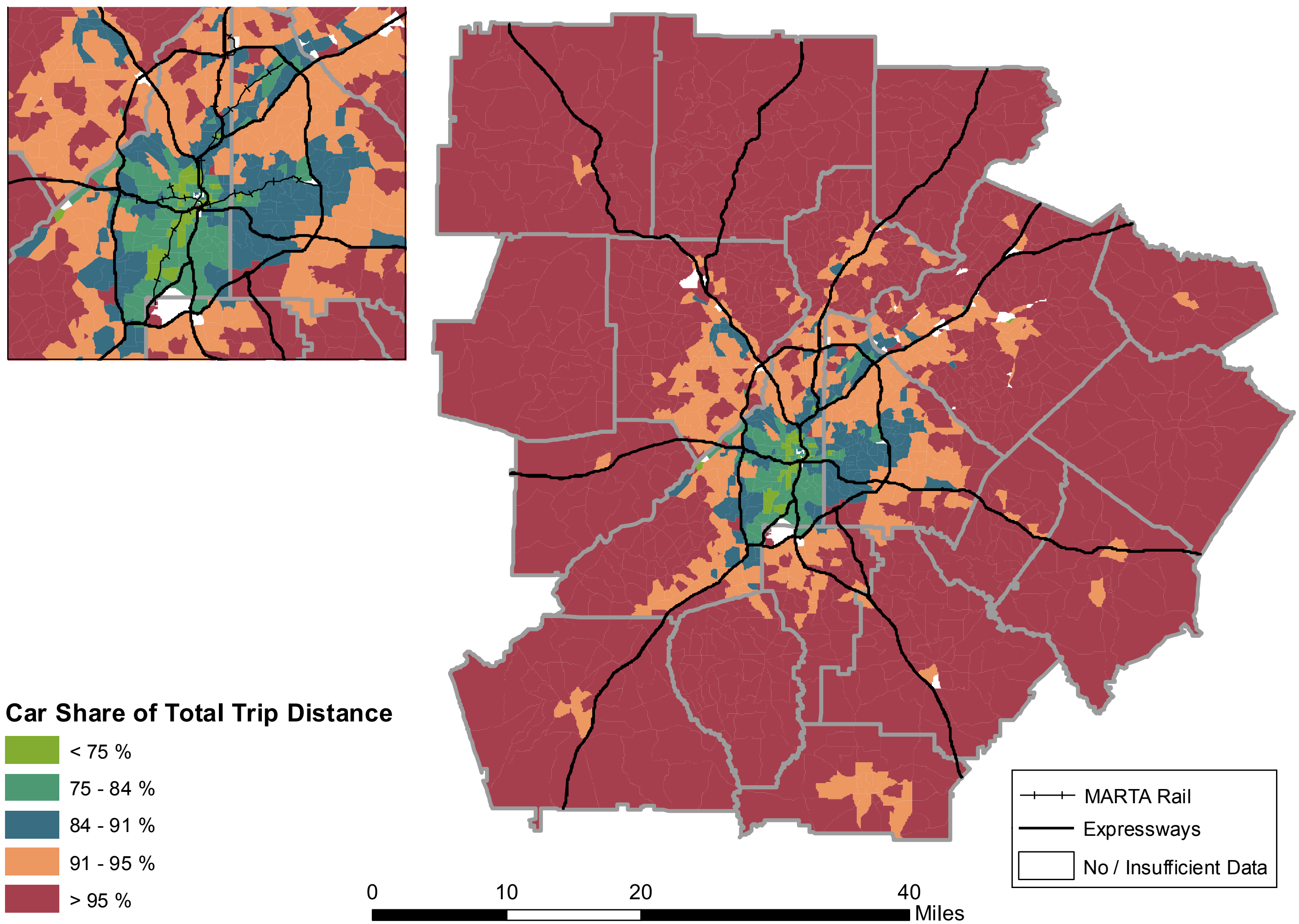
Note: walking trips represent a small portion of total trip distance in the Atlanta region. The index is relative.

Map 7 – Transit Share of Total Trip Distance by Traffic Analysis Zone

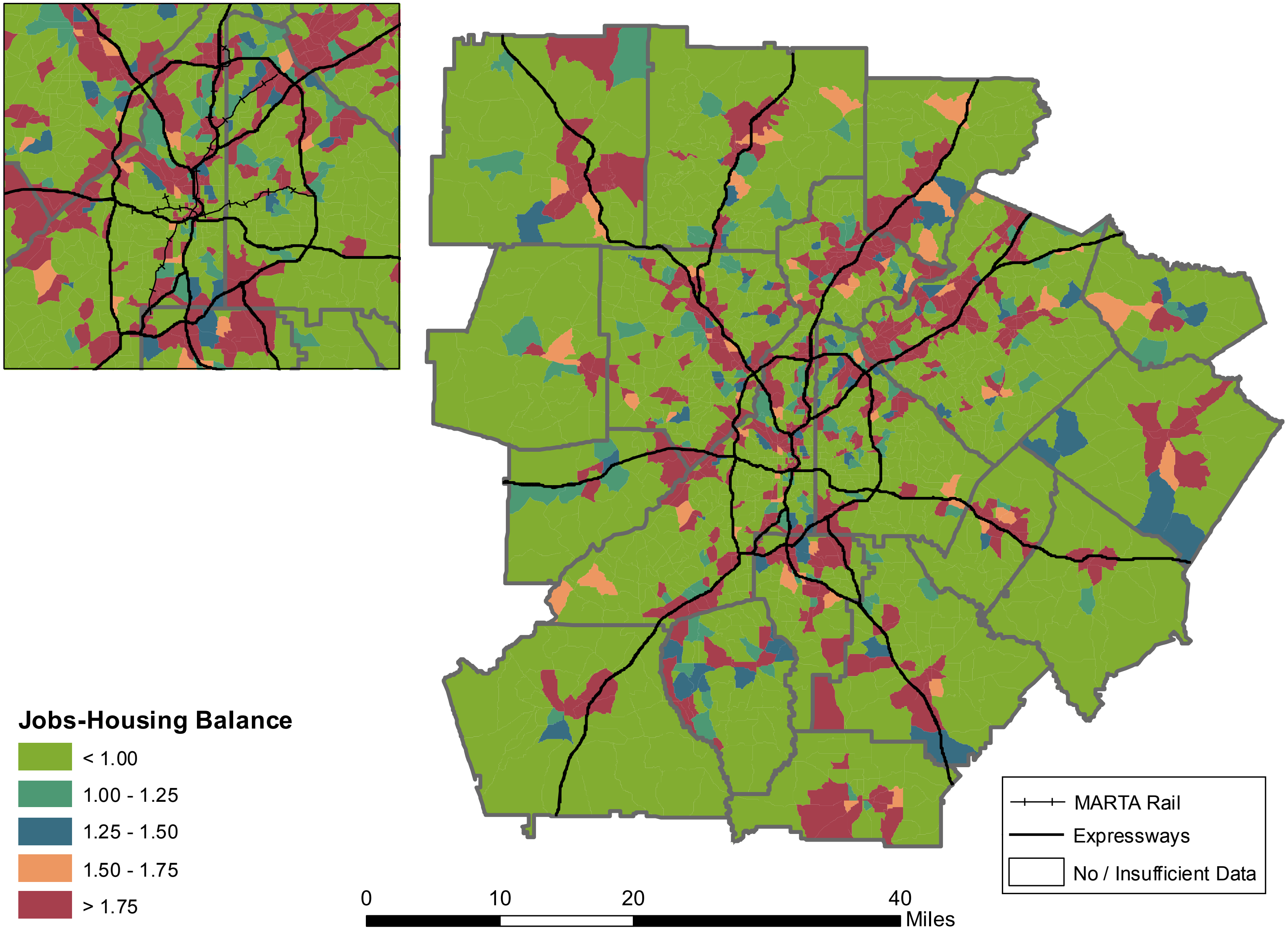


Note: Transit trips represent a small portion of total trip distance in the Atlanta region. The index is relative and inclusive of transit trips that originated as automobile trips that traveled to park and ride lots throughout the region.

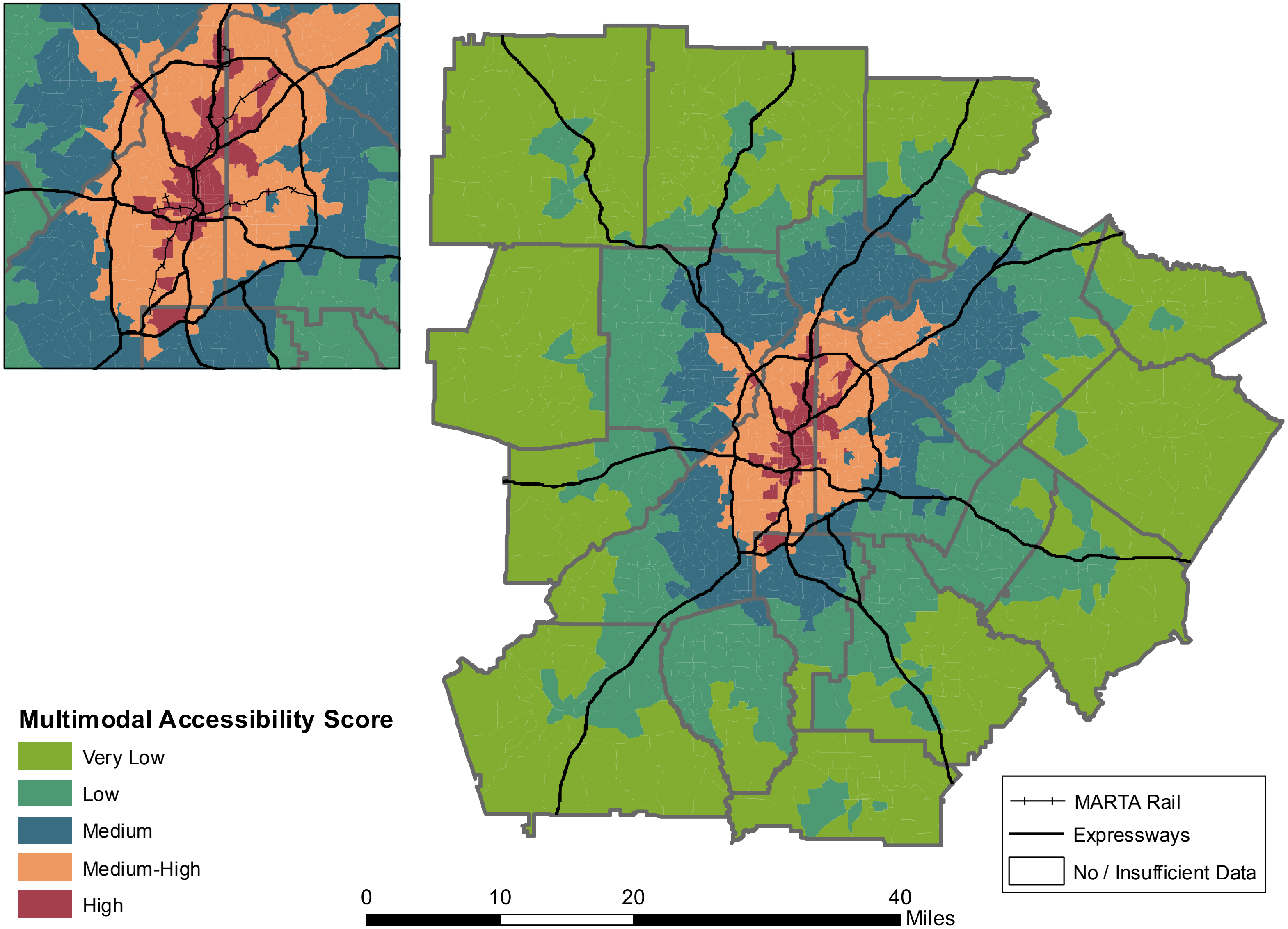
Map 8 – Automobile Share of Total Trip Distance by Traffic Analysis Zone



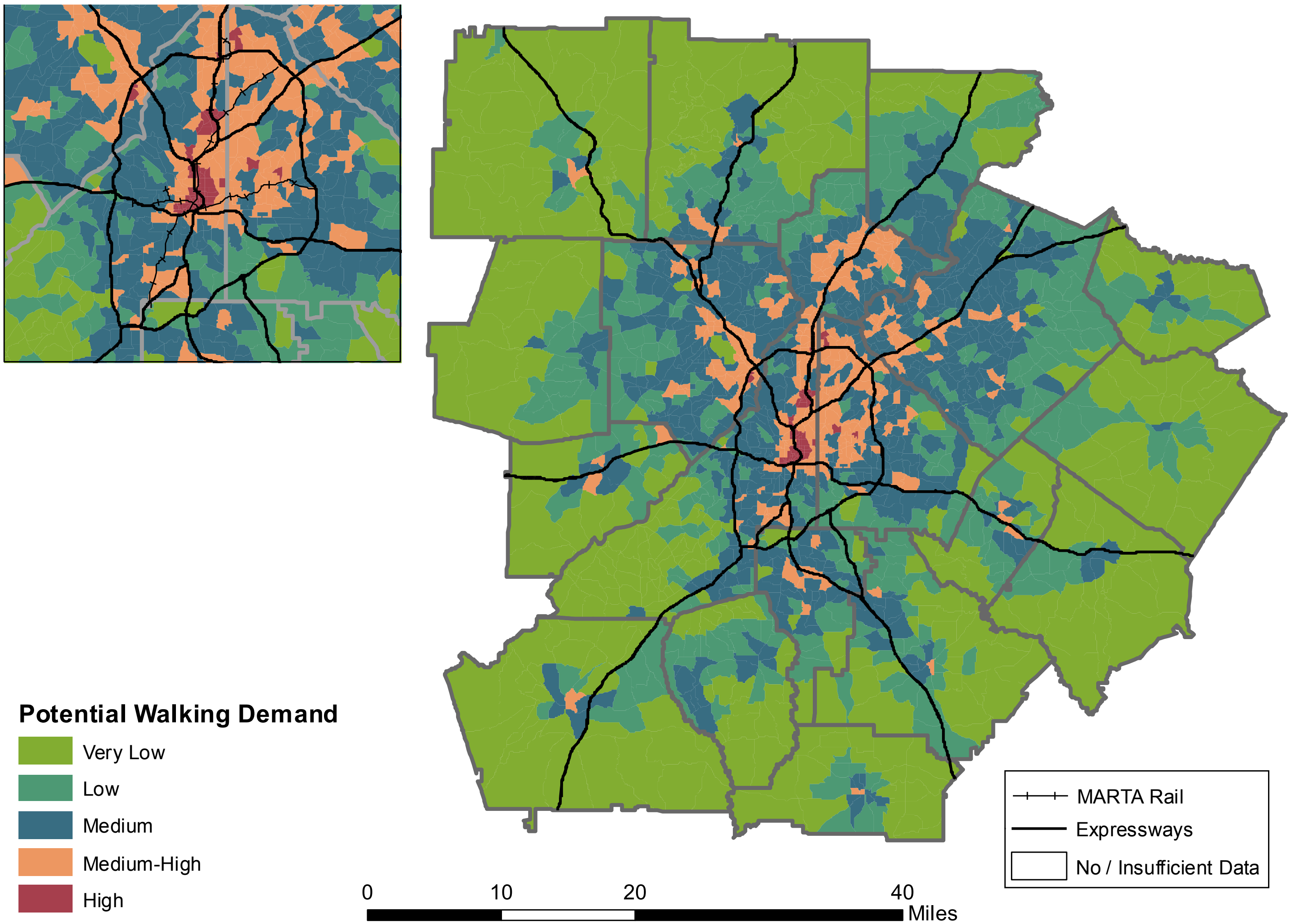
Map 9 – Jobs-Housing Balance by Traffic Analysis Zone



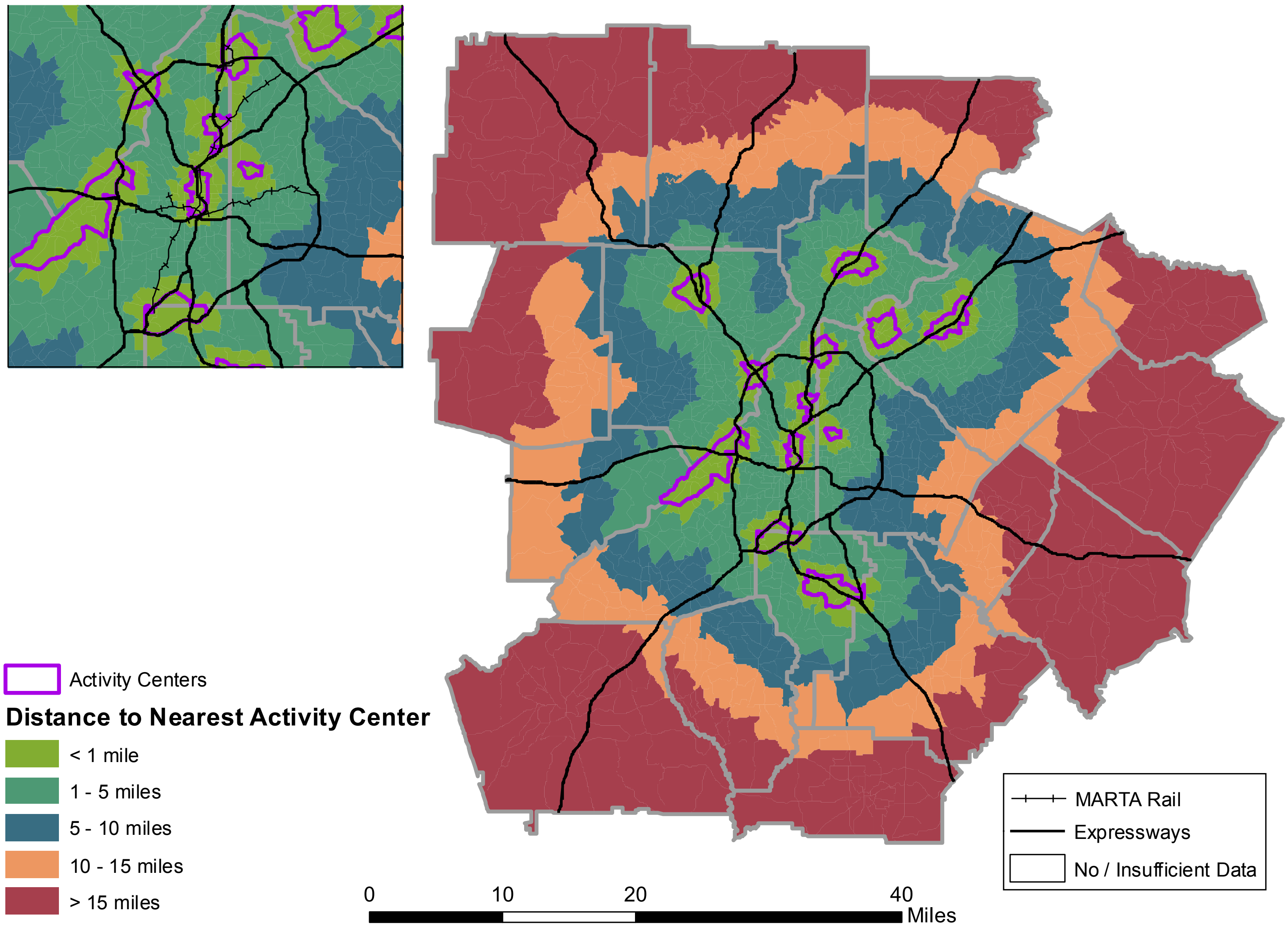
Map 10 – ARC Multimodal Accessibility Index by Traffic Analysis Zone



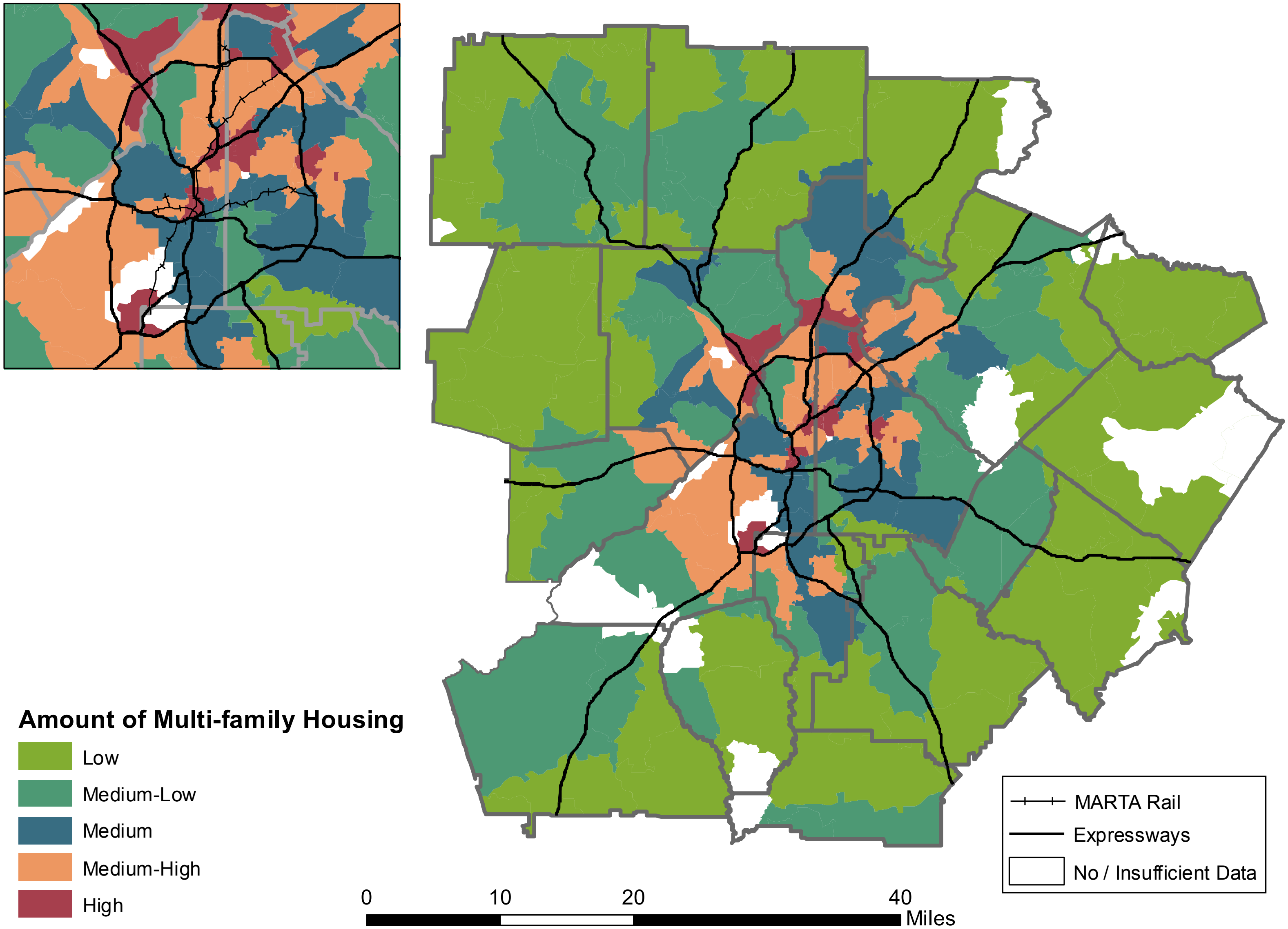
Map 11 – ARC Walkability Index by Traffic Analysis Zone



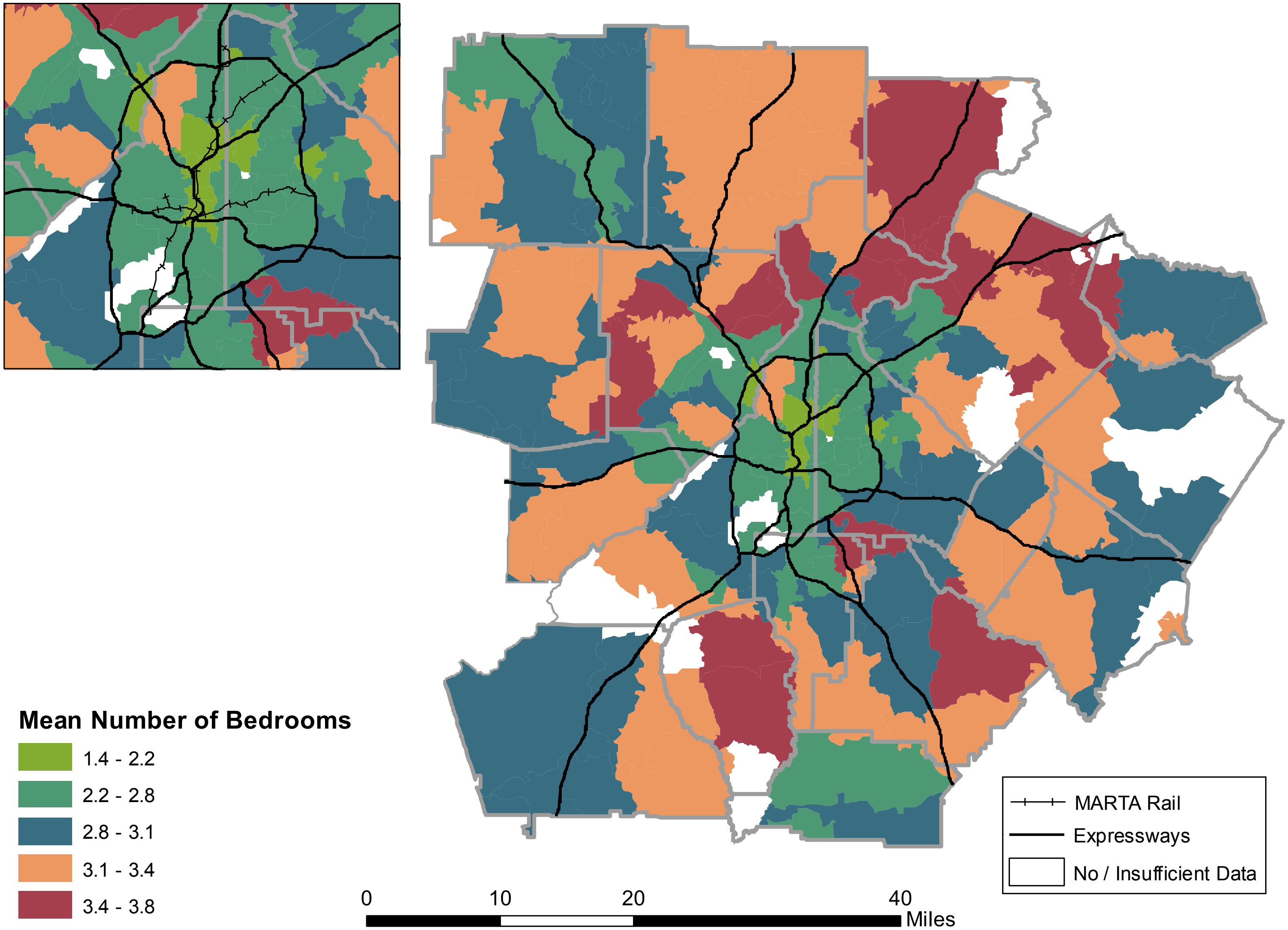
Map 12 – Distance to Regional Activity Centers by Traffic Analysis Zone



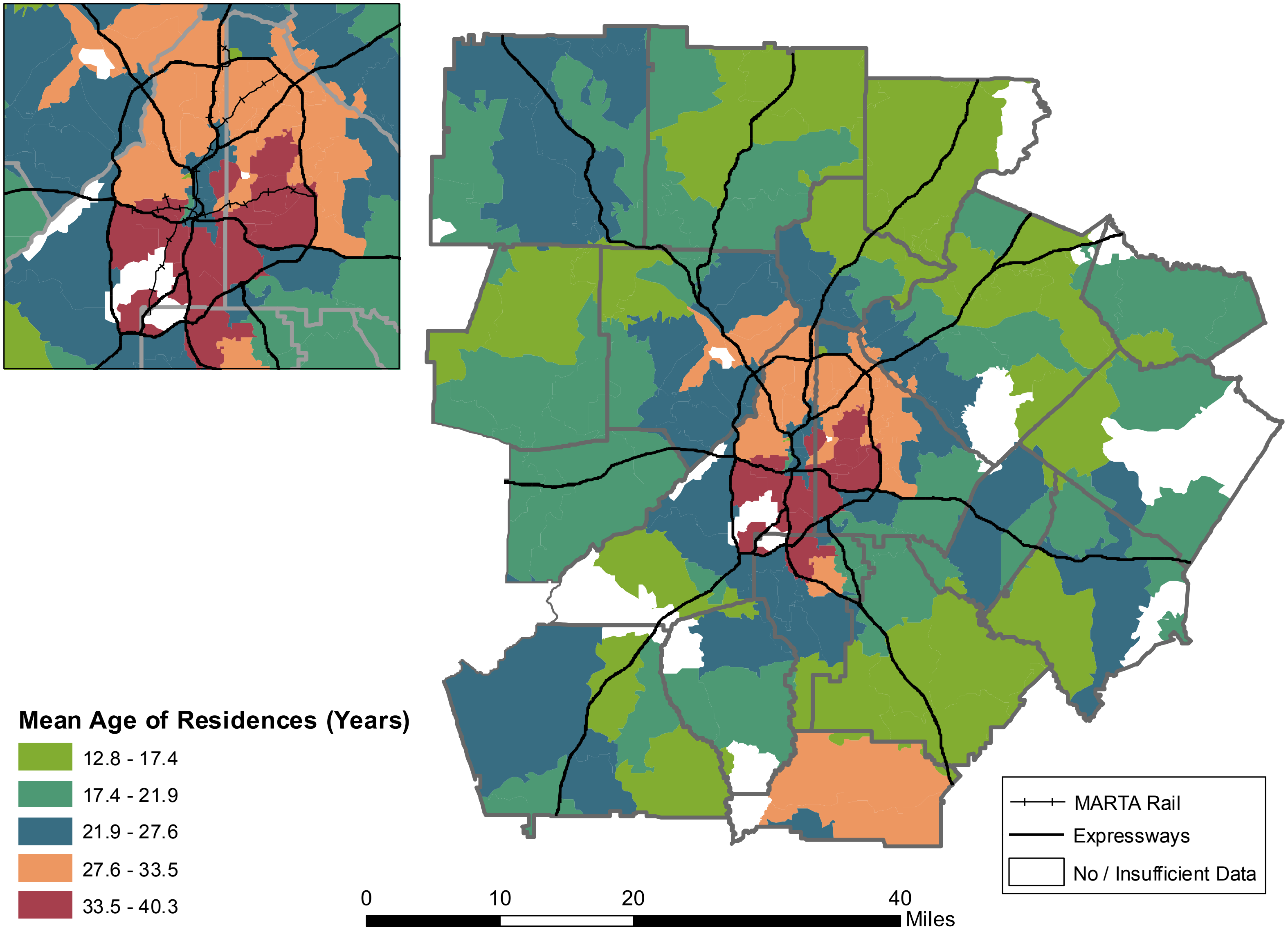
Map 13 – Mean Number of Housing Units per Development by Zip Code



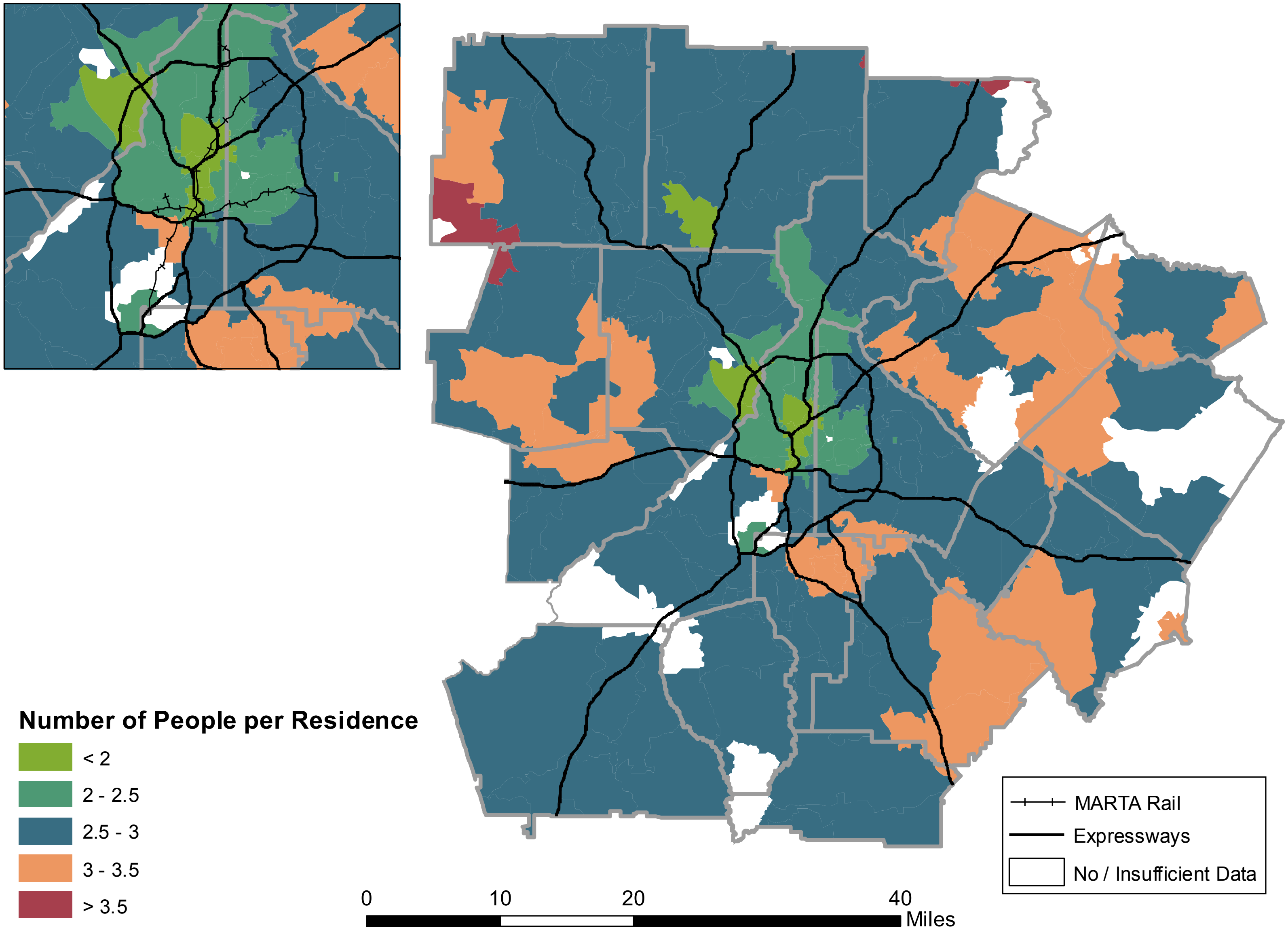
Map 14 – Mean Number of Bedrooms for Residences by Zip Code



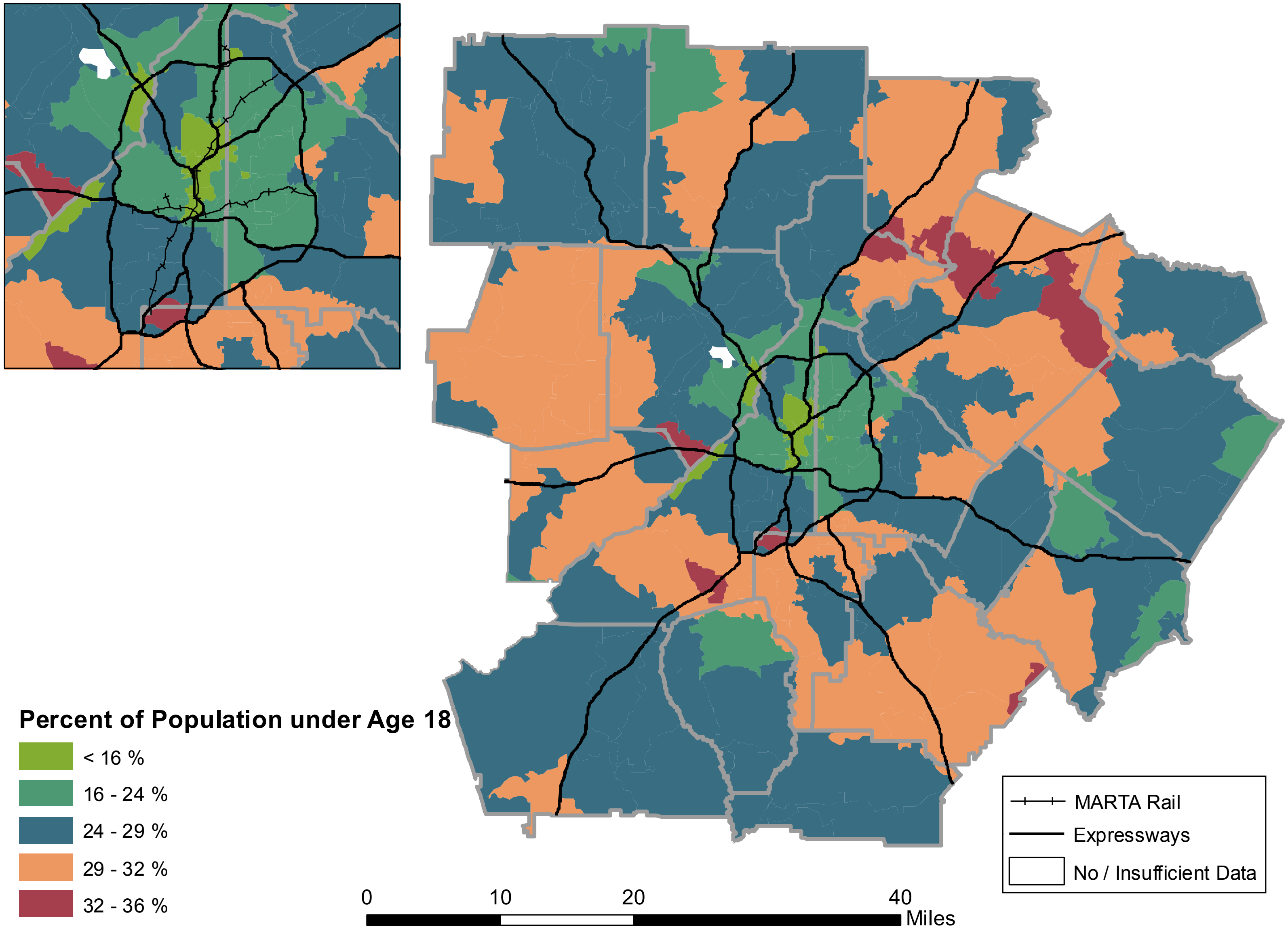
Map 15 – Mean Age of Residences by Zip Code



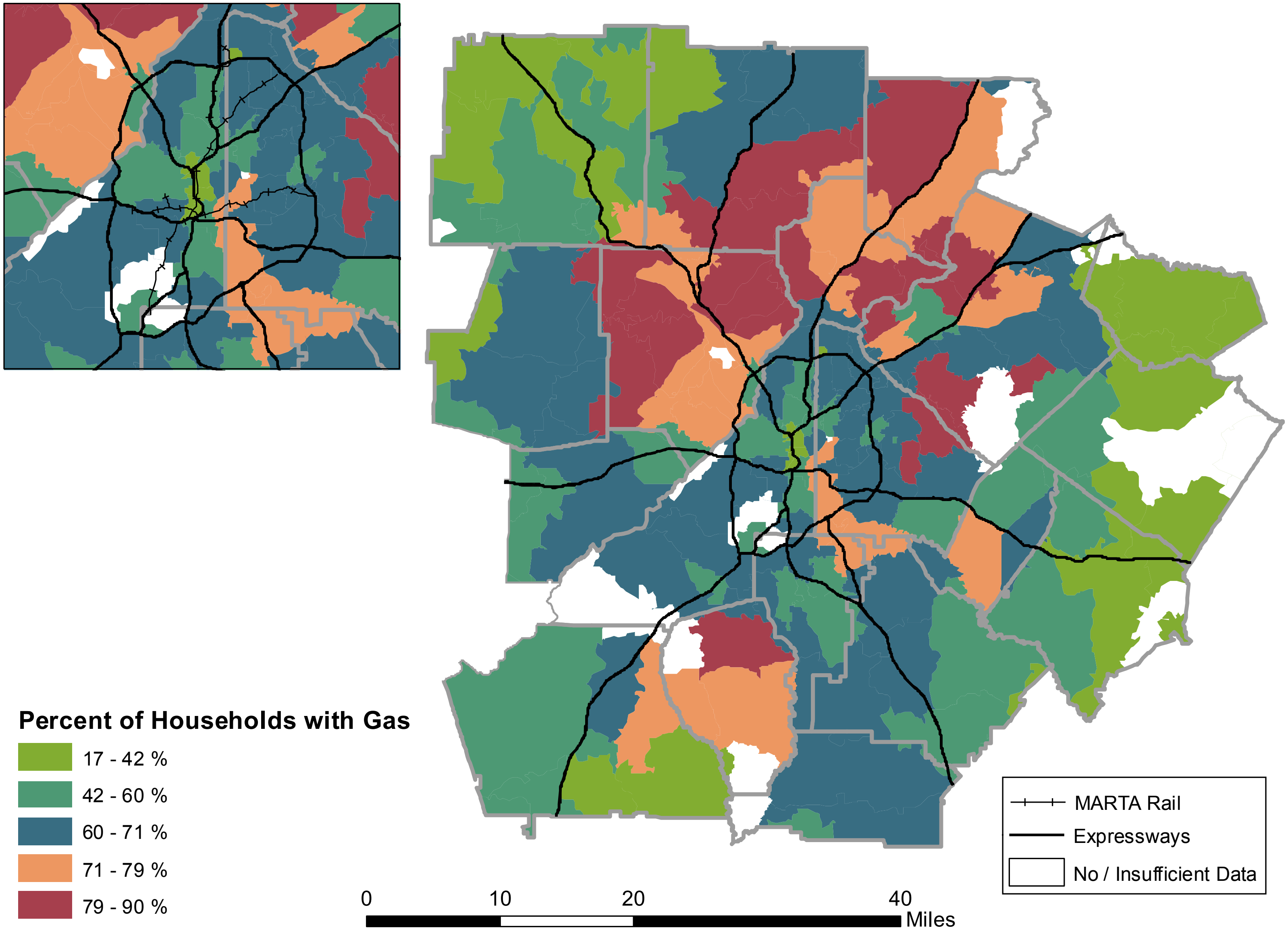
Map 16 – Mean Household Size (Number of People) by Zip Code



Map 17 – Percent of Population under the Age 18 by Zip Code



Map 18 – Percent of Households with Natural Gas by Zip Code



Map 19 – WalkUPs, LCI and MARTA Transit Stations in the Atlanta Region