The Impact of Mixed-use Development, Small Businesses, and Walkability on Carbon Emissions in Cool Climate Cities

Maged Zagow (mzagow@hawk.iit.edu)
IIT: Illinois Institute of Technology https://orcid.org/0000-0002-1701-0411

Research Article

Keywords: United States (US), Chicago, zip codes, CO2 emissions, recreation facilities

Posted Date: January 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1213981/v1

Abstract

United States (US) cities of cool climate zone such as Chicago and Boston are witnessing a reduction in carbon emissions potentially due to focusing on public transportation, and alternative energy resources. It's difficult to validate or deny optimal practices and regulations due to a lack of reliable data on carbon emissions and urban comparative studies amongst metropolitan areas. Therefore, we have examined at the relationship between land use, walkability, socioeconomics variables and carbon dioxide emissions at the zip code level. The current study compares the carbon footprints of four metro regions in cool climatic zone 5 with a model of all US zip code, to generate a benchmarking predictive model for climate change across all US zip codes. Our research shows that increasing number of businesses within walkable distance in cool climate reduces CO2 emissions. This signifies that enhancing walkability in cities and remodeling of retail, art, entertainment, and recreation facilities in accordance with urban sustainability policies can greatly cut down CO2 emissions.

Introduction

Approximately half of the world's population lives in urban regions, and this percentage is expected to rise to 60% by 2030. Cities utilize 60-80% of the vast bulk of global energy and produce a closely similar percentage of CO2. According to the Organization for Economic Co-operation and Development (OECD), more urbanized nations generate higher CO2 emissions. Greenhouse gas (GHG) emissions in OECD member cities are mainly driven by energy-consuming services such as lighting, heating, cooling, appliance and electronics usage, and transportation, rather than by industrial operations. Growing urbanization is predicted to give rise to a significant increase in energy use and CO2 emissions, particularly in non-OECD Asian and African countries, where urban energy use is likely to shift from CO2-neutral (biomass and waste) to CO2-intensive energy sources (Kamal-Chaoui 2009).

Planning urban land use may substantially contribute to alleviating fundamental urban challenges. Several urban challenges are difficult to plan for because of the segregated land-use patterns difficulty. These concerns include urban sprawl, environmental sustainability, and socioeconomic sustainability. According to one estimate, metropolitan areas accounted for 67% of worldwide primary energy consumption and 71% of energy-related CO2 emissions in 2006. (Outlook 2008). This means that as cities grow, so do CO_2 emission (Dhakal 2008) (P. Poumanyvong 2010) (B.C. O'Neill 2010).

Energy consumption, and consequently carbon emissions, are largely determined by how power is generated and used in buildings, and how people move around in cities. The density and the spatial structure of cities have a significant impact on energy consumption, particularly in the transportation and construction sectors. Increased density has the potential to drastically reduce urban energy usage. For example, Japan's urban regions are almost five times denser than those of Canada, while the former consumes around 40% of the power consumed by the latter. The proportions are relatively comparable when nations with similar geographical contexts and heating requirements, such as Denmark and Finland, are considered. Denmark's metropolitan regions are four times denser than Finland, while the Danes utilize around 40% less power than the Finns do. (OECD, Competitive Cities in the Global Economy 2006).

Urban carbon emissions are also governed by the population's lifestyle, geographical configuration, and public transportation availability. Consistent with that, North American nations relying significantly on personal vehicles create 50% more CO2 emissions than European countries. Although the USA has the greatest per capita carbon emissions amongst the OECD member countries, Los Angeles, with its strong reliance on personal vehicles, emits more CO2 than New York, despite having the country's highest population density (60% higher than Los Angeles) (OECD, The Economics of Climate Change Mitigation: Policies and Options for Global Act ion beyond 2012 2009).

There are many benefits of reducing carbon emissions. These include benefits to public health, cost savings and efficiency, energy security and infrastructural upgrades, and a boost in urban quality of life. These additional non-climate advantages may also assist to explain why urban areas face fewer trade-offs between economic expansion and GHG emission reduction. For instance, GHG emission reductions may boost human health to such an extent that they cover the local costs of emissions reductions in major part. Policies aimed at reducing GHG emissions through increased energy efficiency can result in large cost savings, and the energy savings can quickly offset the original investment expenditures.

Long blocks and larger streets, according to Jane Jacobs in her book The Death and Life of Great American Cities, encouraged people to rely more on vehicles, which led to traffic congestion. Short blocks make it possible for residents to walk to all the destinations they require, eliminating the need for a car. Development that is both residential and commercial focuses more on the dynamic activities that take place in the public domain rather than tangible facilities like buildings. Rather, it is preoccupied with the following idea: 'Life between buildings is richer, more exciting, and more gratifying than any combination of architectural ideas,' argues Jan Gehl. This is a quote from Gehl (Gehl 1980). Development that is a mix of residential, retail, office, and other purposes is known as mixed-use because it provides a variety of uses for urban property, including all of these. To guarantee that urban space preserves the ability for high levels of quality urbanism, mixed-use development supports the adoption of measures to avoid preventing it. A mixed-use development emphasizes a layout that encourages people to stay in one place for longer periods of time, which helps to integrate them into their surroundings.

Energy usage and carbon emissions may be reduced through better urban planning. According to Marshall (Marshall 2008) (Y. Chen, Estimating the relationship between urban forms and energy consumption: a case study in the Pearl River Delta, 2005–2008 2011) (R. Madlener 2011). According to (Breheny 1995) (O. Mindali 2004) (P. Rickwood 2008), there is a connection between urban form, urban transportation energy usage, and the related carbon dioxide (CO_2) emissions (Steemers 2003). Past studies include those by Anderson et al., 1996; and Reckien et al., 2007. For varying densities, there is still some debate over the link between urban design and energy consumption and CO_2 emissions from even transportation, and actual research on how transportation and buildings interact to impact energy and CO_2 emissions is lacking. Automobile's regulations that limit the number of miles driven by vehicle also reduce emissions of greenhouse gases. As a result of mixed land use, automobile patterns have been reduced in a similar manner. According to some research (Brownstone 2009) and experience (Fang 2008), the type of vehicle used is influenced by land use. There is a paucity of research on CO_2 emissions and urban form. For this reason, many studies assess urban form by looking at population density. It is popular in landscape ecology (Gustafson 1998) to employ spatial metrics, sometimes known as "landscape metrics," as a quantitative tool to define urban forms (J. S. M. Herold 2002) (X. L. M. Herold 2003) (J. Huang 2007).

Philippe Barlaa looked at the factors that contribute to greenhouse gas emissions from urban transportation. Individual and household socio-economic factors, as well as land use and transportation supply features near a person's home and workplace, all have an influence. They discover that emissions are highly dependent on the gender, professional position, age, family structure, and income level of the responder. Variables such as land use and public transportation provision differ greatly between the two places. When calculating the elasticity of emissions in relation to land use and transit supply variables, such as, there is a minor indication according to (Philippe Barlaa 2011). Any decrease in car miles resulting from an increase in mixed land use should likewise result in a decrease in greenhouse gas emissions, according to logic. According to Frank et al. (2011), the greenhouse gas emissions from mixed land use were roughly equal to those from car kilometers driven (Lawrence D. Frank 2011). It is unusual to employ landscape metrics with energy or CO_2 since they are used to measure spatial forms and patterns in the landscape. (R.V. O'Neill 1988) (K. McGarigal 2002). recently estimated this relationship in the Pearl River Delta. "A contiguous set of cells in the same map category," is how landscape metrics describe a patch (M.G. Turner 2001).

According to (Brownstone 2009) and experience (Fang 2008), the type of vehicle used is influenced by land use. Any decrease in car miles resulting from an increase in mixed land use should likewise result in a decrease in greenhouse gas emissions, according to logic. According to Frank et al. (2011), the greenhouse gas emissions from mixed land use were roughly equal to those from car kilometers driven (Lawrence D. Frank 2011). The promotion of walking and bicycling as modes of transportation is one of the primary advantages of mixed-use development. When it comes to pedestrian trips, the effect of mixed-use is higher than the reduction in car miles. According to Ewing and Cervero (2010), walking trips rise by 15% on average for every 1% increase in land-use entropy, and by 0.25 percent for every 1% decrease in walking distance to a store (Ewing 2010) (Kuzmyak 2006) (Boarnet 2008).

The promotion of walking and bicycling as modes of transportation Is one of the primary advantages of mixed-use development. Mixed-use developments have a higher influence on pedestrian trips than on car kilometers travelled. They predict that for every 1% rise in land-use entropy, walking trips increase by 15%, and that for every 1% decrease in walking distance to a shop, walking trips increase by 0.25 percent (Ewing 2010) (Kuzmyak 2006) (Boarnet 2008).

Most planet-warming greenhouse gases are emitted by transportation, according to research. Many today's emissions in American cities and suburbs are caused by automobile pollution (Nadja Popovich 2019). According to the findings of that study, even though the United States has implemented a strategy to reduce carbon dioxide emissions by switching from coal to cleaner natural gas, transportation remains the country's largest source of emissions. According to the EPA, suburban contributes the most 60 percent of all S.U.V. and pickup truck emissions.

According to (Zagow 2020) There were relationships between geographical indices of urban form and CO_2 emissions, according to the findings. the research found an inverse association between mixed-use density and CO_2 emissions, implying that a low-density city with more companies emits less CO_2 than a hybrid metropolis, resulting in a healthier environment. Low density and greater recreation amenities are likely to encourage people to dwell in these locations, emphasizing the relevance of density cities as a source of CO_2. This research adds to the growing body of knowledge about how mixed-use development models change in response to changing environmental, social, and economic factors.

Despite a 14 percent increase in population and a 24 percent increase in car miles driven, Massachusetts has been successful in lowering GHG emissions. Since 2005, significant reductions in GHG emissions from the electric sector have contributed significantly to the decrease in gross GHG emissions. Furthermore, despite economic expansion and unpredictable (and, at times, harsh) weather conditions, the Commonwealth's nation-leading energy efficiency measures have managed to limit energy needs in buildings (Massachusetts, GHG Emissions and Mitigation Policies 2021).

Although many cool-climate states have made significant progress in reducing greenhouse gas emissions but most of the initiatives are limited to the following without understanding the role of mixed-use development, facilities distribution, the urban fabric, and socioeconomic factors. There are several initiatives to plan and coordinate steps to address climate change, and each of the following efforts is actively trying to continue and develop (Massachusetts, Climate Change Planning Efforts 2018).

- Initiative on Transportation and Climate; Since 2010, the Mobility and Climate Initiative (TCI) has brought together 13 Northeast and Mid-Atlantic counties to enhance transportation, promote the clean energy economy, and decrease transportation-related emissions.
- A New Energy Perspective: The six New England states published a "Goal Statement" in October 2020, expressing their vision for a clean, economical, and dependable regional electric grid in the twenty-first century (NESCOE 2020).
- The United States Climate Alliance: The United States Climate Alliance is a bipartisan group of 24 governors dedicated to meeting the Paris Agreement's targets for decreasing greenhouse gas emissions. To minimize greenhouse gas emissions, the United States Climate Alliance relies on renewable energy, low/zero emission vehicle requirements, hydrofluorocarbon laws, resilience or adaptation strategies, and green infrastructure banks.
- Regional Initiative to Reduce Greenhouse Gases: The Regional Greenhouse Gas Initiative (RGGI) is a collaborative effort by states in the Northeast and Mid-Atlantic to minimize CO_2 emissions from big fossil-fueled power facilities. The Regional Greenhouse Gas Initiative (RGGI) is a regulatory initiative that employs market incentives.
- A Comprehensive Energy Plan: The Commonwealth's energy demands for power, transportation, and thermal conditioning are projected in the Comprehensive Energy Plan (CEP), which was released in December 2018.
- Commission on Transportation's Future; The Commission looked at predicted changes in technology, climate, land use, and the economy in January 2018 to see how they would affect transportation between 2020 and 2040, including Climate Change and Resilience, Electrification of the Transportation System, Self-driving and connected vehicles, Public Transportation and Mobility Services, and Demographics and Land Use

Purpose

We looked at a variety of spatial measures and approaches for describing urban shape in this research. Using our indices, we looked at the CO2 distribution, form, and fragmentation of urban neighborhoods as well as socioeconomic characteristics. CO2 emissions by zip code may be found for the entire country in the United States. To determine If mixed-use development is related to carbon emissions, then mixed-use development with a high number of businesses and more walkable will have a lower carbon emission.

So, why climate zone will affect the co2 emissions? According to (Harvey 2018), he claimed that rising carbon dioxide levels in the atmosphere might have a direct impact on the climate system. In other words, even if global temperatures remain stable, greater CO2 concentrations may continue to have an impact on the world. As a result, in addition to the Paris climate agreement's global temperature objectives of 2 degrees Celsius, some scientists are pushing for an explicit restriction on carbon dioxide concentrations (Harvey 2018). Regardless of what occurs with average global temperatures, scientists confirm that rising CO2 levels may lead to an increase in extreme weather and climate events (Nations 2021).

According to the latest data from the world's benchmark atmospheric monitoring station in Hawaii, the Mauna Loa Observatory, was released by the US National Oceanic and Atmospheric Administration and the Scripps Institution of Oceanography, reiterating how carbon dioxide (CO2) emissions continue to be a key driver of climate change. And because CO2 has a long lifetime in the atmosphere many generations would likely endure a series of natural shocks linked to climate change like rising temperatures, more extreme weather, melting ice, rising sea level and all the associated impacts (Nations 2021).

Moreover, why we choose climate zoon 5? Although that cities like Chicago and Boston in cool climate is witnessing a reduction in carbon emissions, but still witnessing extreme weather and climate events that affect those cities. It focusses more on public transportation, and alternative energy resources, but mixed-use development, and increasing small businesses in walkable district decrease carbon emissions. It's difficult to validate or deny optimal practices and regulations due to a lack of reliable data on carbon emissions and urban comparative study amongst metropolitan areas. We looked at the link between land use, walkability, socioeconomics variables and carbon dioxide emissions at the zip code level. It's important to know if and how land use changes impact carbon emissions.

Data on census tracts, geographic characteristics, and pertinent socioeconomic indicators identified in the literature study are used to fulfil the stated goal. Using this information, we looked at how number of businesses, walkability and the socio-economic and geographical factors that define US urban form interact. Such connections have significant policy implications for the development of low carbon cities in the United States, where city governments have centered their carbon mitigation approach primarily around transportation and infrastructure. We believe that our research will add to the ongoing discussion on the relationship between urban design and CO_2 emissions and help us better understand the role that spatial form plays in sustainable urban development.

Table 1
climate zones definitions (Amanda D. Smith 2014)

Climate zone	Description
Climate zone 0	Extremely Hot-Humid (0A), Dry (0B)
Climate zone 1	Very Hot – Humid (1A), Dry (1B)
Climate zone 2	Hot – Humid (2A), Dry (2B)
Climate zone 3	Warm – Humid (3A), Dry (3B) / Warm -Marin (3C)
Climate zone 4	Mixed – Humid (4A), Dry (4B) / Mixed -Marin (4C)
Climate zone 5	Cool – Humid (5A), Dry (5B) / Cool -Marin (5C)
Climate zone 6	Cold – Humid (6A), Dry (6B)
Climate zone 7	Very Cold (7)
Climate zone 8	Subarctic/Arctic (8)

Cool climate – Zone 5

Zone 5 of the IECC describes the chilly climate of the United States. An area with a chilly climate has between 5,400 and 9,000 heating degree days (on a foundation of 65°F). A continental climate means that winters are extremely cold and snowy, while summers are moderate to hot, with plenty of thunderstorms to go around. Various air masses clash in this region, including those from Canada and the Gulf of Mexico. As a result, we have an unpredictable climate, with periods of poor weather interspersed with bright, sunny days and rapid changes in temperature, humidity, cloudiness, and wind direction.

In zoon 5, precipitation is plentiful, with an average annual rainfall of 1,100 millimeters (43 inches). It is also evenly spread throughout the year. Winter brings snow, while summer brings thunderstorms in the afternoon or evening, as well as certain weather disturbances that may bring some wet days (Council 2012).

The winter season, which lasts from December to mid-March, is bitterly cold, with daily highs around 0°C (32°F) and lows as low as -15°C (five degrees Fahrenheit). Blizzards, which blow ice and snow at high speeds, may make it feel much colder. Snowfalls are common, and they can be heavy enough to cause genuine snowstorms if conditions are right. Weeks of snowfall result in a buried landscape (Energy n.d.).

From mid-March through mid-June, the weather remains unreliable, with pleasant days punctuated by the return of frigid temperatures. During the winter months like March and even April, it might snow often, especially at the beginning of the month when the weather is still cold. Though it's still early in the year, temperatures are already reaching or above 25°C (77°F).

A hot and humid summer lasts from mid-June until the end of August. Conditions can vary greatly throughout this season, from chilly, rainy days with highs around 23/24°C (73/75°F) to hot, humid days around 28°C (82°F), when the sun is shining, and a sea wind is blowing. Even heat waves, with daytime temperatures reaching or above 35°C (95°F) and nighttime temperatures hovering around 23/25°C (73/77°F), can occur sometimes. It's nice to have sunny days in the summer, but they're often punctuated by violent afternoon thunderstorms, occasionally accompanied by hail.

Autumn lasts from September through November, is the most warm and steady season of the year. Even while the weather is still hot and humid in early September, with sunny skies and a few afternoon thunderstorms, the temperature quickly drops until mid-October, when it begins to get cold. Already in November, it's becoming chilly, and the first snowfalls may be here. During this time of year, it rains very frequently.

There are four separate seasons in the cold environment, each with their own set of circumstances. There is a wide range of precipitation kinds and quantities, with modest monthly and seasonal average fluctuations. A great deal of variation in the year-to-year weather conditions within the metropolitan region. An abundance of storms throughout the year.

Data sources

Census Bureau data, zip code demographics, and a block census were used to compile the statistics. The US Census Bureau used three different waves of data between 1990 and 2010. Zone diversity in residential and nonresidential zones can only be compared using population data that has clearly defined geographic borders. Only residential land-use categories are used to quantify diversity in this approach, which uses a range of land-use categories. When it comes to understanding a city's demographics, knowing its zip code distribution is essential. You may examine trends within a city and even narrow your search to a specific area using zip code demographics. The information included in a zip code can also reveal socioeconomic traits like a person's wealth and educational attainment.

Known as "Zip Code Business Patterns," the census has collected extensive data on the overall number of businesses in every zip code since 1994. This data covers for-profit enterprises like supermarkets and graphic design firms, as well as nonprofit and government organizations like museums and religious institutions. It also includes supermarkets and graphic design firms. It also provides further information on the number of businesses by class of employment size, which describes the level of employment and the dynamics of employment by company size.

Research variables

Table 2
CO_2 Emission Regression analysis Variables

Variables	Definition	Source
Dependent		
Co_2 emission	Carbon emission in each zip code	This data is from CoolClimate Network - RAEL, UC Berkeley, the use of data is under permission of Christopher M. Jones, Ph.D. Program Director
Number of Businesses	Total number of Bussinesses in each zip code	census-2016
walk score	data is used to assess the closeness of facilities in a third mixed-use variable	(Hamidi 2010)
Independent		
Social and Economic		
Percentage of Occupied housing units	Percentage of occupied housing units to total housing units in each zip code	census-2010-zcta
Percent of people using public transportation	Percentage of people using public transportation	'American Community Survey 2009-2013
Environmental and Wildlife Organizations	Number of Environmental and Wildlife Organizations in each zip code	census-2010-zcta
Civic & social organizations	Number of Civic & social organizations in each zip code	census-2010-zcta
Vehicle miles traveled	Total miles driven by Vehicle	'American Community Survey 2009-2013
Type of facilities		
Education facilities	Number of education facilities in each zip code	census-2016
Accommodations and food services	Number of accommodations and food services in each zip code	census-2016
Retail trade facilities	Number of retail facilities in each zip code	census-2016
Arts, entertainment, and recreation facilities	Number of arts, entertainment, and recreation facilities in each zip code	census-2016
Urban Fabric		
Street factor	Average block size excluding rural blocks of more than one square mile, percentage of small urban blocks of less than one hundredth of a square mile	Using Census Feature Class Code (CFCC) values, Reid Ewing and Shima Hamidi filtered out all freeways, unpaved tracks, and other roadways that do not function as pedestrian routes. Divided roadways, which from a pedestrian mobility perspective functions similarly to undivided roadways of the same functional class, were represented in the source data as pairs of (roughly) parallel centerline segments. These were identified by a CFCC value and merged into single segments using GIS tools.

Urban factors

Street factor; In 2010, Reid Ewing and Shima Hamidi created a nationwide database of junction street locations, including a count of streets that meet at each intersection, starting with a 2006 TomTom national data set of street centerlines that ships for ArcGIS. There is a centerline feature in the TomTom data collection for every road segment connecting adjacent junctions, meaning that every intersection is the spatially coincident terminus of three or more road segments. (Hamidi 2010).
Mix factor; A mix factor was created by estimating all three categories of residents in each zip code. It is necessary to extract main components from three mix-related variables to determine the mix factor. This variable reflects three different kinds of land-use mix measurements that may be found in the literature:
1- **Zip Code average job-population balance (job_pop);** For the first two variables, the 2010 Census population data and the LED database's 2010 employment data were used. The first variable is the sum of the number of people and the number of jobs in each zip code. It is one if the zip code has the same ratio of workers to inhabitants as the county area, and it is zero if the zip code only has workers or residents, but not both.

2- Zip code's degree of job mixing (job mix); The total number of employments in each industry is calculated for each zip code. The task mix is then calculated using an entropy formula. When all jobs are in a single sector, the variable equals one; otherwise, it equals zero. Intermediate values are used for situations when there is a mix of sectors inside the zip code. Retail, lodging and food services, finance, the arts and entertainment, as well as health, education, and personal services are all taken into account.

3- Zip code's average Walk Score (walk score); Walk Score Inc. data is used to assess the closeness of facilities in a third mixed-use variable. Different services are weighed differently, and services are discounted as the distance to them rises up to a half-mile. All urban census tracts in the United States have the traditional Walk Score data collected. Zip code population and employment are added together as a percentage of the county population to arrive at weighted values.

Uses of Metropolitan and Micropolitan Statistical Areas

Using Census Bureau data, the Office of Management and Budget (OMB) divides the United States into metropolitan and micropolitan statistical regions. Metropolitan or micropolitan statistical areas have a core population nucleus and nearby settlements that are economically and socially integrated with that nucleus, depending on the definition. CBSA must have at least one city with a population of 10,000 or more, according to the 2010 criteria. Each metro must have at least one urbanized region with a population of at least 50,000 people. An urban cluster of at least 10,000 people but not more than 50,000 must exist in every micropolitan statistical region. A "central county" is one in which at least half of the residents live in urban regions with a population of 10,000 or more, or where at least 5,000 people live in a single urban area with a population of 10,000 or more (counties). CBSA includes "outlying counties" that commute to or from the core counties according to certain conditions (Census 2020).

Comparative analysis: Nine Urban models

Table 3
Number of cases for each urban model

Model	*Detroit Metro*	*Reno Metro*	*Columbus Metro*	*Chicago Metro*	*Boston Metro*	*Zone 5 MICRO*	*Zone 5 METRO*	*Zone 5 CITEIS*	*Zone 5*
Number of cases	253	37	191	391	541	1483	4714	4066	8292

Results and Descriptions

Correlation analysis:

Table 4
Pearson Correlation between CO_2 emissions and urban Socioeconomics Variables.

	walkscore	Number of Businesses	mix factor	Retail Trade	Education	Accommodation and Food Services	Health	Arts, Entertainment, and Recreation	Finance	street factor	Percentag of Occupied Housing Units
All data	-0.21**	-0.11**	0.02**	-0.16**	-0.04**	-0.19**	-0.11**	-0.09**	-0.07**	0.07**	0.23**
Zoon 5	-0.22**	-0.07**	0.03**	-0.15**	0.00	-0.19**	-0.12**	-0.08**	-0.06**	0.10**	0.12**
Cities	-0.39**	-0.15**	-0.16**	-0.23**	-0.04*	-0.30**	-0.20**	-0.15**	-0.13**	-0.04*	0.36**
metro	-0.35**	-0.13**	-0.13**	-0.20**	-0.03	-0.27**	-0.17**	-0.13**	-0.10**	-0.03*	0.33**
Micro	-0.11**	-0.19**	0.04	-0.21**	-0.17**	-0.22**	-0.21**	-0.18**	-0.16**	0.03	0.44**
Boston	-0.53*	-0.32**	-0.13**	-0.33**	-0.23**	-0.49**	-0.32**	-0.21**	-0.21**	-0.32**	0.32**
Chicago	-0.40**	-0.19**	-0.26**	-0.32**	-0.06	-0.35**	-0.26**	-0.30**	-0.24**	-0.21**	0.12*
Columbus	-0.47**	-0.23**	-0.21**	-0.30**	-0.17*	-0.30**	-0.23**	-0.09	-0.10	-0.07	0.43**
Detroit	-0.52**	-0.19**	-0.36**	-0.35**	-0.10	-0.31**	-0.13*	-0.04	-0.06	-0.28**	0.63**
** Significant at the 0.01 level (2-tailed)											
* Significant at the 0.05 level (2-tailed)											

In all zone 5 zip codes:

The amount of CO_2 emitted in each zip code is directly proportional to the number of vehicle miles driven. This link supports the theory that a vehicle emits more CO_2 the longer it is driven. CO_2 emissions per zip code are adversely associated with the total number of businesses. One argument is that as the business population of a zip code grows, so does its transportation infrastructure, lowering CO_2 emissions. The fraction of people who use public transportation is often inversely proportional to CO_2 emissions per zip code. Less CO_2 is released into the environment when more people use public transportation. The Walkscore and CO_2 emissions per zip code have a modest linear connection. This connection backs up the theory that as more people walk to meet their requirements, less CO_2 is released into the atmosphere. According to Figure 4, we notice that many metro areas in climate zone 5 witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value for all US zip codes

Zone 5 CITEIS

The amount of CO_2 released per zip code is directly proportional to the number of miles driven in an automobile. This connection backs up the theory that longer travels emit more CO_2. CO_2 emissions per zip code are adversely associated with population density. Less CO_2 is released into the environment when more people use public transportation. CO_2 emissions per zip code are considerably negatively connected to the number of businesses. According to one idea, taking public transportation minimizes CO_2 emissions. CO_2 emissions per zip code show a small negative linear association with retail outlets. As more retail outlets promote public transportation, the amount of CO_2 released into the atmosphere decreases. CO_2 emissions are reduced by using public transportation to support additional Accommodation and Food Services. The fraction of people who use public transportation is often inversely proportional to CO_2 emissions per zip code. This corresponds to the assumption that if more people walked or worked from home, there would be less CO_2 released into the atmosphere. In general, CO_2 emissions per zip code are inversely proportional to the land use mix. People may be able to access more services in one zip code while driving less, reducing CO_2 emissions. The Walkscore and CO_2 emissions per zip code have a modest linear connection. This connection backs up the theory that as more people walk to meet their requirements, less CO_2 is released into the atmosphere. According to Figure 6, we notice that many cities in climate zone 5 witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Zone 5 METRO

CO_2 emissions per zip code and automobile miles travelled have a significant upward (positive) linear relationship. According to this study, a longer route results in higher CO_2 emissions. Retail stores have a minor negative linear association in terms of CO_2 emissions per zip code. One argument is that encouraging people to use public transit decreases CO_2 emissions. The hospitality and food services businesses are slightly associated with CO_2 emissions by zip code. CO_2 emissions are reduced by using public transportation to support extra lodging and dining services. In general, population density is inversely proportional to CO_2 emissions. When more people use public transportation, less CO_2 is released into the atmosphere. CO2 emissions are proportional to the land use mix in each zip code. When more land uses are combined, people drive less, which reduces CO_2 emissions. The Walkscore and CO_2 emissions per zip code have a modest linear connection. This link backs up the premise that increasing the number of people who walk decreases CO_2 emissions. CO_2 emissions per zip code are inversely proportional to the number of inhabited dwelling units. Increased occupancy in a zip code might explain higher CO_2 emissions. According to Figure 7, we notice that many metro areas in climate zone 5 witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Zone 5 MICRO

The amount of CO_2 released per zip code is directly proportional to the number of miles driven in an automobile. This connection backs up the theory that longer travels emit more CO_2. CO_2 emissions are reduced by using public transportation to support additional Accommodation and Food Services. CO_2 emissions per zip code are inversely connected with retail store sales. If more retail outlets promote public transportation, the amount of CO_2 released into the atmosphere may be reduced. The occupancy of a residential unit has a mildly positive linear relationship with CO_2 emissions per zip code. One explanation is that when the number of occupied residential units in a zip code grows, CO_2 emissions grow as well. CO_2 emissions per zip code are strongly connected with family income. According to one idea, as household wealth rises, so do CO_2 emissions.

According to Figure 8, we notice that micro areas in climate zone 5 witnessing a minimum value through regression analysis.

Boston Metro– Massachusetts

The amount of CO_2 released per zip code is directly proportional to the number of miles driven in an automobile. This connection backs up the theory that longer travels emit more CO_2. The Walkscore and CO_2 emissions per zip code have a modest linear connection. This connection backs up the theory that as more people walk to meet their requirements, less CO_2 is released into the atmosphere. CO_2 emissions are reduced by using public transportation to support additional Accommodation and Food Services. Public transportation usage shows a somewhat negative linear association with CO_2 emissions per zip code. Individuals may be encouraged to participate in more environmentally friendly and sustainable activities through civic and social organizations. If more retail outlets promote public transportation, the amount of CO_2 released into the atmosphere may be reduced. The street factor has a negative relationship with CO_2 emissions per zip code in general. People would not have to go as far if there were more street crossings, reducing CO_2 emissions. CO_2 emissions per zip code are positively associated with the percentage of occupied dwelling units. One explanation is that when the number of occupied residential units in a zip code grows, CO_2 emissions grow as well. According to Figure 9, we notice that west side of Boston is witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Chicago Metro – Illinois

The amount of CO_2 released per zip code is directly proportional to the number of miles driven in an automobile. This connection backs up the theory that longer travels emit more CO_2. The Walkscore has a strong relationship with CO_2 emissions per zip code. This connection backs up the theory that as more people walk to meet their requirements, less CO_2 is released into the atmosphere. CO_2 emissions per zip code are inversely associated with the mix factor. If the job-to-population ratio improves, jobs mix, and people walk more, individuals will be able to access more services in a single zip code. CO_2 emissions per zip code show a small negative linear association with retail outlets. If more retail outlets promote public transportation, the amount of CO_2 released into the atmosphere may be reduced. Health care facilities have a negative relationship with CO_2 emissions per zip code. Using public transportation, for example, minimizes CO_2 emissions. Finance facilities have a somewhat negative linear link in terms of CO_2 emissions per zip code. Taking public transportation, for example, lowers the amount of CO_2 released into the environment. The street factor has a negative relationship with CO_2 emissions per zip code in general. People would not have to go as far if there were more street crossings, reducing CO_2 emissions. According to Figure 10, we notice that north side of Chicago is witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Columbus Metro– Ohio

CO_2 emissions per zip code are strongly linked to the number of occupied housing units. One explanation is that when the number of occupied residential units in a zip code grows, CO_2 emissions grow as well. The Walkscore has a strong relationship with CO_2 emissions per zip code. This connection backs up the theory that as more people walk to meet their needs, less CO_2 is released into the atmosphere. CO_2 emissions per zip code are adversely associated with population density. Less CO_2 is released into the environment when more people use public transportation. CO_2 emissions per zip code are significantly associated with land use mix. People may be able to access more services in one zip code while driving less, reducing CO_2 emissions. The use of public transportation and CO_2 emissions per zip code have a substantial downward (negative) linear relationship. CO_2 emissions per zip code are inversely associated with the mix factor. CO_2 emissions per zip code are adversely associated with the number of businesses. One argument is that as the business population of a zip code grows, so does its transportation infrastructure, lowering CO_2 emissions. CO_2 emissions and environmental and wildlife organizations have a little negative linear association. Individuals may be encouraged to adopt more eco-friendly and sustainable practices by environmental and animal organizations. CO_2 emissions per zip code show a significantly negative linear association with these categories. Individuals may be encouraged to participate in more environmentally friendly and sustainable activities through civic and social organizations. According to Figure 11, we notice that center of Columbus is witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Detroit Metro – Michigan

Gas mileage is highly associated with CO_2 emissions by zip code. Longer trips emit more CO_2, according to this site. Walkscore and CO_2 emissions per zip code are significantly connected. That less CO_2 is released into the environment when more people walk supports this relationship. CO_2 emissions per zip code are inversely proportional to population density. Less CO_2 is released into the environment when more people use public transportation. Between transit use and CO_2 emissions per zip code, there is a substantial negative linear relationship. Less CO_2 is released into the environment when more people use public transportation. Climate Change and Civic & Social Organizations are significantly connected. Civic and social organizations can inspire people to be more eco-friendly. The mix factor is inversely associated with CO_2 emissions. Making increasing use of public transportation cuts CO_2 emissions. CO_2 emissions per zip code are adversely associated to street factor. Many people might save time and money by not driving as far. According to Figure 12, we notice that center of Detroit is witnessing critical values through regression analysis. Red (blue) areas indicate that CO_2 emissions in that zip code typically sell at a relatively higher (lower) value.

Methodology And Techniques

Our regression analysis consists of three major categories: CO2 emissions, number of businesses and walkscore. We constructed a statistical regression model for each category with the zip code data from US census. The ordinary least square (OLS) method was used with predictor variables including Percentage of Occupied housing units, Percent of people using public transportation, Environmental and Wildlife Organizations, Vehicle miles traveled, Retail trade facilities, Arts, entertainment, and recreation facilities, Accommodations and food services, Street factor, and mix factor (see Table 2 for a sample of specific variables used). Note: *p < 0.05, **p < 0.01; adjusted R2, which is a measure of the goodness of fit of the line. Not all variables are used in each regression, and blank spaces in columns indicate cases where the variable in question is not significant for the specific regression.

The model can be formulated as

$$\ln Ej = \beta j0 + \sum_{i} \beta ij \bullet \{\backslash\text{rm X}\}\iota + \epsilon j$$

where *j* indicates the categories of number of businesses and walkscore, E_j is CO_2 emissions for each zip code, and X_i means predictor variable whose value is from our dataset from the census data for prediction. We used geographic information systems (GIS) to map zip codes to cool climate zoon 5 divisions using shape files. However, this method will still provide the unbiased mean estimates because of the characteristics of the OLS method. In order to specify the size of uncertainty of a random variable that is a product of other random variables, we have to have correlation coefficients between those original variables for each zip code area. But practically, we do not have the information in the census dataset, so we cannot specify the uncertainty size for them.

Table 5

Regression Analysis for Carbon Emissions, Number of Business and Walkscore for in All US zip codes, Climate zoon 5, Climate zoon 5 Cities, Cli

	all US Zip codes			**Zoon 5**			**Cities**			**Metro**
Variables	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emission
(Constant)	22.567	-63.727	11.891	28.716	-110.343	15.865	18.320	-232.863	16.005	21.418
Walkscore	0.006			-0.014			-0.054			-0.040
Number of Businesses	0.002						0.005			0.007
Mix Factor	0.000	0.366	0.28	0.003	0.316	0.136	-0.002	0.36	0.157	0.000
Retail Trade Stores	0.001	1.674	-0.005	0.004	1.562	0.025	-0.006	1.628	0.027	-0.006
Education Facilities	0.079	5.847	0.082	0.082	3.166	0.054	0.070	2.852	0.057	
Accommodation and Food Services	-0.037	2.231	0.044	-0.078	2.189	0.082	-0.094	2.008	0.06	-0.085
Health Facilities	-0.001	1.036	0.018	0.006	1.272	0.016	-0.006	1.328	0.006	0.000
Arts, Entertainment, and Recreation Facilities	-0.004	2.867	-0.036	0.198	3.464	-0.258	0.182	3.126	-0.187	0.176
Finance Facilities	0.012	3.188	0.03	0.032	3.227	0.04	0.018	3.233	0.046	
Street Factor	0.022	-0.046	-0.218	0.029	0.01	-0.045	0.026	0.325	-0.027	0.026
Mean Vehicle miles traveled	0.001		-0.001	0.001	-0.001		0.001	-0.002		0.001
Percentage of occupied Housing Units	1.870	24.679	1.292	1.883	12.405	2.005	20.367	83.218	8.586	14.705
Percentage of people using public transportation	-0.027	1.161	0.496	-0.117	1.894	1.461	-0.046	1.477	1.303	-0.083
Environmental and Wildlife Organizations	-0.445	21.157	0.173	-0.827	22.539	-0.154	-0.836	25.602	0.089	-0.846
Total (tCO2e/yr)		1.131	0.078		2.691	-0.108		3.25	-0.379	
Adjusted R Square	0.69	0.92	0.65	0.64	0.88	0.55	0.63	0.85	0.55	0.63
N	28122			8292			4066			4714

Table 6

Regression Analysis for Carbon Emissions, Number of Business and Walkscore for in Boston, Chicago, Columbus, and Detroit.

	Boston			**Chicago**			**Columbus**			**Detroit**
Variables	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emissions	Number of Businesses	Walkscore	Carbon Emission
(Constant)	17.759	-93.612	0.151	12.555	-291.778	17.727	25.207	-17.54	5.252	14.407
Walkscore	0.042			0.092			-0.003			0.009
Number of Businesses	-0.001			0.002			-0.003			-0.002
Mix Factor	-0.013	0.002	0.043	-0.048	3.919	0.557	0.013	-0.574	0.65	0.004
Retail Trade Stores	-0.007	1.783	0.014	-0.006	0.052	-0.004	0.003	1.213	0.005	0.009
Education Facilities	0.164	7.595	0.57	0.008	0.543		0.311	1.299	0.016	0.246
Accommodation and Food Services	-0.033	1.68	0.021	-0.019	4.927	0.027	-0.065	3.116	-0.048	-0.061
Health Facilities	0.015	1.851	-0.011	0.008	0.691	-0.03	-0.002	0.946	-0.013	0.006
Arts, Entertainment, and Recreation Facilities	0.100	2.447	-0.199	-0.070	-1.861	-0.043	0.213	9.785	0.219	0.118
Finance Facilities	0.012	2.753	0.031	0.014	0.558	0.024	0.042	3.123	-0.004	0.038
Street Factor	0.020	0.377	0.067	0.057	-2.53	-0.447	0.007	0.801	-0.698	0.046
Mean Vehicle miles traveled	0.001	0.002	-0.004	0.002	-0.031	-0.001	0.001	0.001	-0.001	0.001
Percentage of occupied Housing Units	-6.277	59.221	40.991	0.477	84.093	-8.271	2.300	30.314	23.733	1.649
Percentage of people using public transportation	0.025	-0.985	0.498	0.193	-12.98	0.08	-0.363	7.585	-0.103	0.056
Environmental and Wildlife Organizations	-0.143	-6.198	-1.075	-0.227	98.68	-1.076	-0.749	-22.337	1.769	-0.164
Total (tCO2e/yr)		-0.273	1.529		19.529	0.486		-0.959	-0.024	
Adjusted R Square	0.93	0.96	0.61	0.85	0.56	0.88	0.87	0.99	0.85	0.905
N	541			391			191			253

Prediction intervals here are calculated at the mean points for the explanatory variables for each zip code area. To do this, we executed mean-centered regressions for the nine models and observed the 95% confidence intervals around the intercepts.

Regressions and Results

Regression differs from correlation in that it attempts to include variables in an equation and explain their causal link. I need to develop a model that employs linear regression, commonly known as linear modelling, since I'm trying to describe natural phenomena with equations that only reflect a portion of the overall picture. The results of the linear regression, as well as numerous data sets, are presented in this section. Theoretical explanations and expectations for the connections between the dependent variable and the independent variables, as seen in the findings, are also provided in this section.

The model summary shows the statistical measure of the goodness of fit and the coefficients of determination represented by the adjusted R Square. The adjusted R Square values range from zero to one that indicates how much the line of regression fits the points where one indicates the perfect fit. Therefore, a higher value for the adjusted R Square indicates a better regression model. The ANOVA table shows the significance level of the regression model. The table of coefficients shows the slopes of the independent variables and the constant (intercept).

Conclusion and Policy Implications

This study examined and assessed the principles of mixed-use development in relation to increases in CO_2 emissions in cool climatic zone 5 in the United States. The findings of this investigation are based on zip code-level data. The data was pulled from the census for the 8292-zip code in the United States. In addition, metro regions and micro areas were evaluated as part of the research. In addition, four metropolitan regions are examined in the research. The results of this study include data analysis methodologies, descriptive and other statistical analyses, and regression analyses.

Finding for research

In cool climate zone 5 the Metro and Micro areas Urban model, it was interesting that while the total number of businesses increases, the carbon emissions increases. However, when we focus on Boston, Columbus, and Detroit metro area we find the opposite. more on the hybrid and low, dense metropolis models, the hybrid metropolis model shows more carbon emissions than the low, dense metropolis model. A likely impact is that the hybrid metropolis model attracts more facilities and cars, which creates pollution.

Overall (tCO_2 e/yr) is negatively correlated with the percentage of individuals who take public transportation. Reduced carbon emissions appear to be supported by an increase in the number of companies emitting them. What services or facilities, if any, lead to higher carbon emissions? The upward (positive) linear relationship between carbon emissions and shopping, the arts, leisure, and recreation show no signs of abating.

So, what can be done in cool climate zone 5 to minimize carbon emissions? What type of carbon emission methods make sense considering the patterns of urban creation and mixed-use variety that have been revealed? It'd make sense to incorporate measures to deal with dense, mixed-use growth while also increasing public transit options. To decrease carbon emissions, planners should pay special attention to places with a low street factor and a small number of dwelling units. To reduce or maintain greenhouse gas emissions, it's a good idea to try to turn these areas back into places for shopping, the arts, entertainment, and leisure instead.

What is the process for managing and controlling the land use mix in these situations? In cool climatic zone 5, a mixed-use metropolis with a wide range of residential zones may result in lower carbon emissions. Incorporating more arts, entertainment, and amusement into the design can help cut carbon emissions.

According to one of our findings, geolocation correlation might lead to erroneous conclusions. According to my research, CO_2 emissions are inversely related to the number of firms in an area. The findings of the correlation test were inconsistent, as I discovered. There is a downward trend at the city level. The total (tCO_2e/yr) and the total number of enterprises have a negative link, according to the study of city variation. It has more buildings with many dwelling units than the total (tCO_2e/yr).

General conclusion:

According to the findings of the study, cool climate zone 5 metro regions give a healthy ambiance for people to reside in. People may choose to reside in these locations because of the lower energy and CO_2 emissions of public transportation because of the higher density and greater availability of recreational activities. Increases in mixed-use facility density reduce carbon emissions, according to the study. However, compared to metro areas, carbon emissions are higher in the small, low-population areas. First, when more facilities are built, more public and shared transportation is required. Because of this, a greater portion of the area must use more fossil fuels for heating and cooling.

Research shows that well planned mixed land use within communities has various effects on carbon emissions, according to this study's findings Designing mixed-use areas should take these variables into account, according to the study:

- The sort of mixed-use development chosen should blend in with the neighborhood.
- Commercial developments should take environmental consideration to be acceptable for the community, scaled in size to match the neighborhood, and should provide pedestrians with easy access.
- Retail, arts, entertainment, recreation, and public parks may help cut carbon emissions.
- Public transportation options are more plentiful in large cities than in smaller ones. When looking for measures to lower a city's carbon footprint, one of the most important factors to examine is its public transit system. Investing in public transit is something that cities should do. To entirely avoid carbon emissions, walk or ride your bike wherever feasible. By distributing CO2 emissions among many people, carpooling and public transportation significantly cut CO2 emissions. If electric automobiles are charged with clean power, they produce no CO2.

There is a correlation between regulatory instruments like land use, human needs, and environmental considerations, and the result of this study suggests that a deeper knowledge of this link is needed. It will be necessary to go beyond the standards of Jane Jacobs and the establishment of specific mixed-use zones to deal with this complexity. It's clear that more effort must be done.

Creative procurement, improved screening of infrastructure, transportation, communication networks, and utilities, financial and tax incentives, energy supplier partnerships and regulation, consumer awareness, and green job training programs are just a few of the cities and regions can use to promote green growth. They also have a significant amount of responsibility for leading by example. An effective green growth strategy for cities should focus short- to medium-term job creation and systemic changes in the way cities operate and expand via the continual invention and use of new technologies that increase connectivity and reduce resource consumption. Green infrastructure funds have the potential to dramatically lower the burden on local governments while increasing the efficiency of green investments, thanks to public-private partnerships created by green infrastructure funds.

Declarations

To be used for all articles, including articles with biological applications

Funding (not Funding)

Conflicts of interest/Competing interests (No)

Availability of data and material (upon request)

Code availability (Not applicable)

Authors' contributions (Not applicable)

References

1. Agency IEnvironmentalP (2019) *Climate Change in Illinois.* January 23. Accessed November 16, 2021. https://www2.illinois.gov/epa/topics/climate/Pages/default.aspx
2. Amanda D, Smith, Mago PJ (2014) "Effects of Load-following operational methods on combined heat and power systemefficiency."*Applied Energy*337–351
3. O'Neill BC, Dalton M, Fuchs R, Jiang L, Pachauri S, Zigova K (2010) "Global demographic trends and future carbon emissions." *Proceedings of the National Academy of Sciences* 17521-17526
4. Boarnet MG, Greenwald M, McMillan T (2008) "Walking, Urban Design, and Health: Toward a Cost-Benefit Analysis Framework."*Journal of Planning Education and Research*341–358
5. Breheny M (1995) "The compact city and transport energy consumption."*Transactions of Institute of British Geographers*81–101
6. Brownstone D, Golob T (2009) "The Impact of Residential Density on Vehicle Usage and Energy Consumption."*Journal of Urban Economics*91–98
7. Grimmond CSB, King TS, Cropley FD, Nowak DJ, C Souch (2002) "Local-scale fluxes of carbon dioxide in urban environments: methodological challenges and results from Chicago."*Environmental Pollution*S243-S254
8. Census (2020) *Metropolitan and Micropolitan.* April 1. Accessed October 7, 2021. https://www.census.gov/programs-surveys/metro-micro/about.html
9. Conor K, Gately LR, Hutyra, Ian Sue Wing (2015) "Cities, traffic, and CO2: A multidecadal assessment of trends, drivers, and scaling relationships." *PNAS* 4999–5004
10. Council IC (2012) *2012 IECC - International Energy Conservation Code.* ICC. https://basc.pnnl.gov/images/iecc-climate-zone-map
11. Tong D, Zhang Q, Zheng Y, Caldeira K, Shearer C, Hong C, Qin Y (2019) & Steven J. Davis. "Committed emissions from existing energy infrastructure jeopardize 1.5°C climate target." *Nature* 373–377
12. Dhakal S (2008) "Climate change and cities: the making of a climate friendly future." In *Urban Energy Transition: From Fossil Fuel to Renewable Power*, by P. Droege, 173-182. Oxford: Elsevier
13. Energy, Office of Energy Efficiency (2021) & Renewable. n.d. *Climate Zones buildings.* Accessed November 2, https://www.energy.gov/eere/buildings/climate-zones
14. Ewing R, Cervero R (2010) "Travel and the Built Environment: A Meta-Analysis."*Journal of the American Planning Association*265–294
15. Fang HA (2008) "A discrete–continuous model of households' vehicle choice and usage with an application to the effects of residential density."*Transportation Research*736–758
16. Gehl J (1980) Life Between Buildings. Island Press
17. Gustafson EJ (1998) "Quantifying landscape spatial pattern: what is the state of the art?." *Ecosystems* 143-156
18. Hamidi RE (2010) and Shima. *Measuring Urban Sprawl and Validating Sprawl Measures.* University of Utah, National Institutes of Health, 114. Accessed 1 4, 2015. http://gis.cancer.gov/tools/urban-sprawl/
19. Harvey C (2018) *CO2 Can Directly Impact Extreme Weather, Research Suggests.* June 21. Accessed November 16, 2021. https://www.scientificamerican.com/article/co2-can-directly-impact-extreme-weather-research-suggests/
20. Hugh S, Baker RJ, Millar DJ, Karoly U, Beyerle BP, Guillod D, Mitchell H, Shiogama S, Sparrow T, Woollings, Myles R Allen. 2018. "Higher CO2 concentrations increase extreme event risk in a 1.5°C world."*Nature Climate Change*604–608
21. Huang J, Lu XX, Sellers JMA (2007) "A global comparative analysis of urban form: applying spatial metrics and remote sensing."*Landscape and Urban Planning*184–197
22. McGarigal K, Cushman SA, Neel MC, Ene E (2002) *FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps.* http://www.umass.edu/landeco/research/fragstats/fragstats.html
23. Kamal-Chaoui L and Alexis Robert (2009) Competitive Cities and Climate Change. OECD, PARIS
24. Kuzmyak R, Baber C, Savory D (2006) "Use of a walk opportunities index to quantify local accessibility."*Transportation Research*145–153
25. Lawrence D, Frank MJ, Greenwald S, Kavage AD (2011) AN ASSESSMENT OF URBAN FORM AND PEDESTRIAN AND TRANSIT IMPROVEMENTS AS AN INTEGRATED GHG REDUCTION STRATEGY. The State of Washington, Department of Transportation, Seattle, WA
26. Herold M, Scepan J, Clarke KC (2002) "The use of remote sensing and landscape metrics to describe structures and changes in urban land uses."*Environment and Planning A*1443–1458
27. Herold M, Liu XH, Clarke KC (2003) "Spatial metrics and image texture for mapping urban land use."*Photogrammetric Engineering & Remote Sensing*991–1001

28. Turner MG, Gardner RH, O'Neill RV (2001) "Landscape Ecology in Theory and Practice. Pattern and Process." 99–108. New York: Springer-Verlag
29. Maher K (2019) "U.S. Carbon Emissions Rose 3.4% in 2018 as Economy Surged."*The Wall Street Journal*, January 8
30. Marshall Lindsey JL, Schofer KA, Gray (2011) "The effect of residential location on vehicle miles of travel, energy consumption and greenhouse gas emissions: Chicago case study." *Transportation Research Part D: Transport and Environment* 1-9
31. Marshall JD (2008) "Energy-efficient urban form."*Environmental Science & Technology*3133–3137
32. Massachusetts C (2018) *Climate Change Planning Efforts.* December. Accessed November 16, 2021. https://www.mass.gov/info-details/climate-change-planning-efforts
33. — (2021) *GHG Emissions and Mitigation Policies.* Accessed November 16, 2021. https://www.mass.gov/info-details/ghg-emissions-and-mitigation-policies
34. Popovich N (2019) Denise Lu. *The Most Detailed Map of Auto Emissions in America.* October 10. https://www.nytimes.com/interactive/2019/10/10/climate/driving-emissions-map.html?mc=adintl&ad-keywords=IntlAudDev&subid1=TAFI&fbclid=IwAR1uj0bislYPSTe1oxdLx20JTKe_vH8tHZuR9cic1uUMrPpZxaR_daEXeUE&dclid=CIzetrzaoOYCFS8C0wodw
35. Nations U (2021) *Chilliest Spring in years is cold comfort as CO2 emissions rise: WMO.* June 8. Accessed November 16, 2021. https://news.un.org/en/story/2021/06/1093592
36. NESCOE (2020) *New England States Vision Statement.* October 16. Accessed November 16, 2021. https://nescoe.com/resource-center/vision-stmt-oct2020/#_ftn1
37. Mindali O, Raveh A, Salomon I (2004) "Urban density and energy consumption: a new look at old statistics."*Transportation Research Part A*143–162
38. OECD (2006) Competitive Cities in the Global Economy. OECD, Paris
39. OECD (2009) The Economics of Climate Change Mitigation: Policies and Options for Global Act ion beyond 2012. OECD, Paris
40. Outlook WE (2008) Paris:International Energy Agency
41. Poumanyvong P, Kaneko S (2010) "Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis."*Ecological Economics*434–444
42. Rickwood P, Glazebrook G, Searle G (2008) "Urban structure and energy – a review."*Urban Policy and Research*57–81
43. Philippe Barlaa LF, Miranda-Morenob M, Lee-Gosselina (2011) "Urban travel CO2 emissions and land use: A case study for Quebec City." *Environment* 423-428
44. Prospects WU (2009) Revision, Population Division, Department of Economic and Social Affairs. the United Nations Secretariat, New York
45. Madlener R, Sunak Y (2011) "Impacts of urbanization on urban structures and energy demand: what can we learn for urban energy planning and urbanization management?."*Sustainable Cities and Society*45–53
46. O'Neill RV, Krummel JR, Gardner RH, Sugihara G, Jackson B, De Angelis DL, Milne BT, Turner MG, Zygmunt B, Christensen SW, Dale VH, Graham RL (1988) "Indices of landscape pattern."*Landscape Ecology*153–162
47. Song Y, Knaap G-J (2004) Measuring the effects of mixed land uses on housing values. Reg Sci Urban Econ 34:663–680
48. Steemers K (2003) "Energy and the city: building and transport."*Energy and Buildings*3–14
49. Turner MG, Gardner RH, O'Neill RV (2001) Landscape ecology in theory and practice: Pattern and process. Springer, New York
50. Chen Y, Li X, Zheng Y, Guan Y, Liu X (2011) "Estimating the relationship between urban forms and energy consumption: a case study in the Pearl River Delta, 2005–2008."*Landscape and Urban Planning*33–42
51. Chen Y, Li X, Zheng Y, Guan Y, Liu X (2011) "Estimating the relationship between urban forms and energy consumption: a case study in the Pearl River Delta, 2005–2008."*Landscape and Urban Planning*33–42
52. Zagow M (2020) "Does mixed-use development in the metropolis lead to less carbon emissions? " Urban Climate

Figures

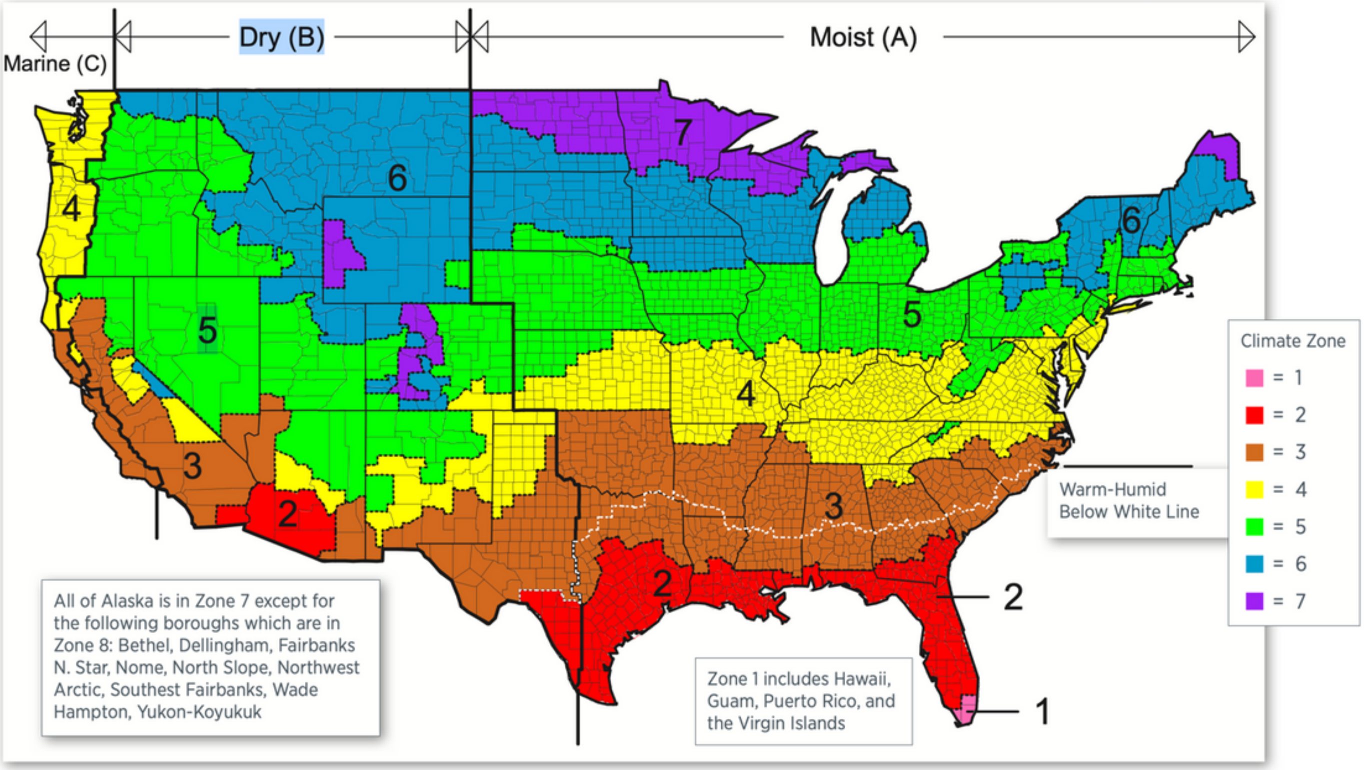

Figure 2. International Energy Conservation Code (IECC) climate regions

Figure 1

US climate regions (Council 2012)

Figure 2

Descriptive Statistics of CO_2 emissions for each model

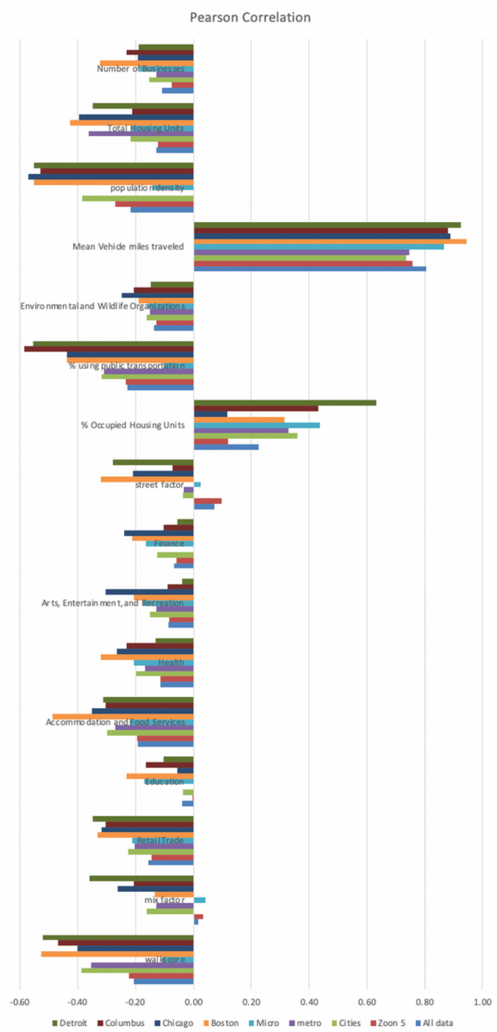

Figure 3

Pearson Correlation between CO2 emissions and urban Socioeconomics Variables.

Figure 4

Heat map based on residuals extracted from a regression featuring CO_2 emissions for All US zip codes.

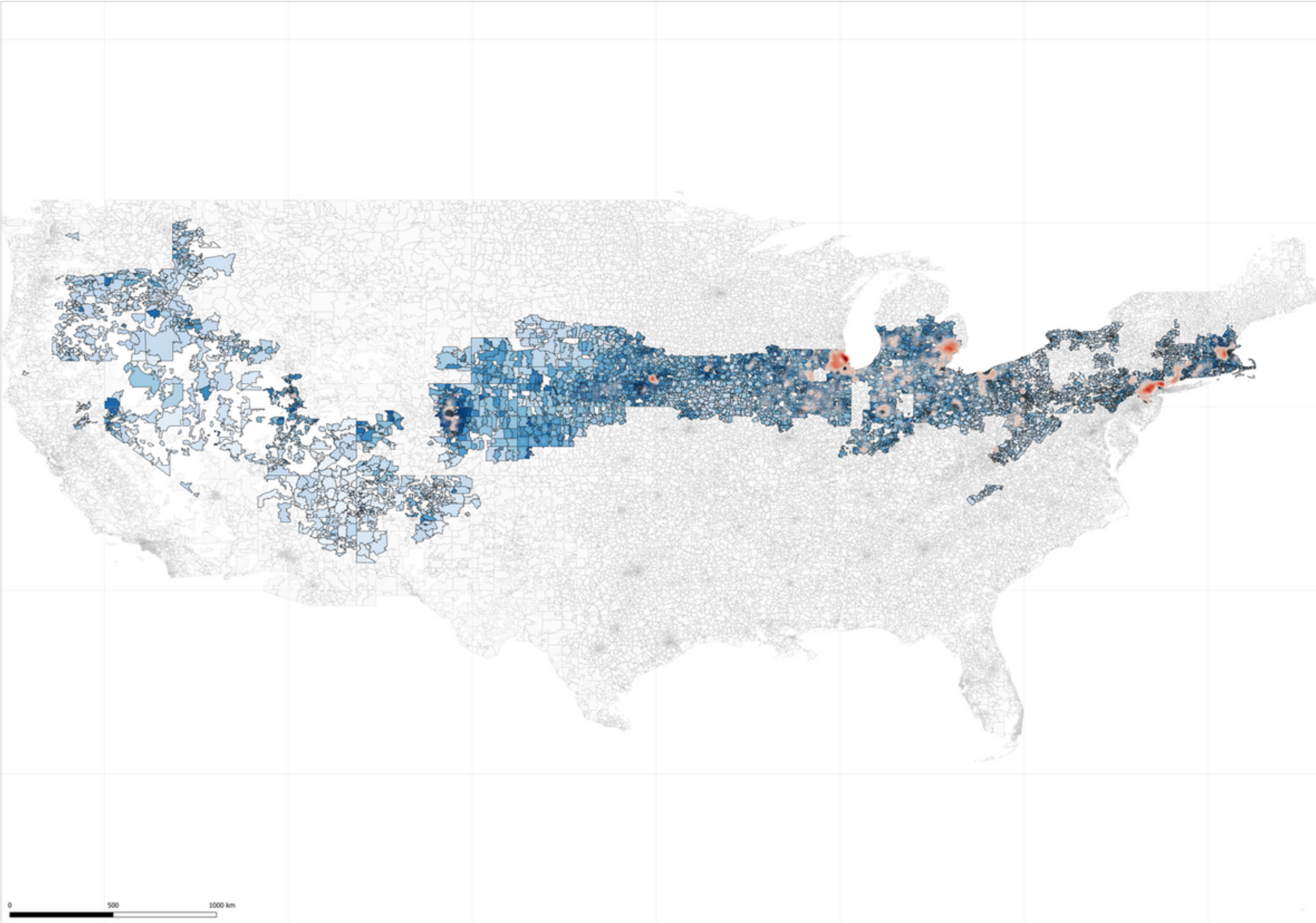

Figure 5

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Cool climate zone 5 zip codes

Figure 6

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Cool climate zone 5 cities zip codes

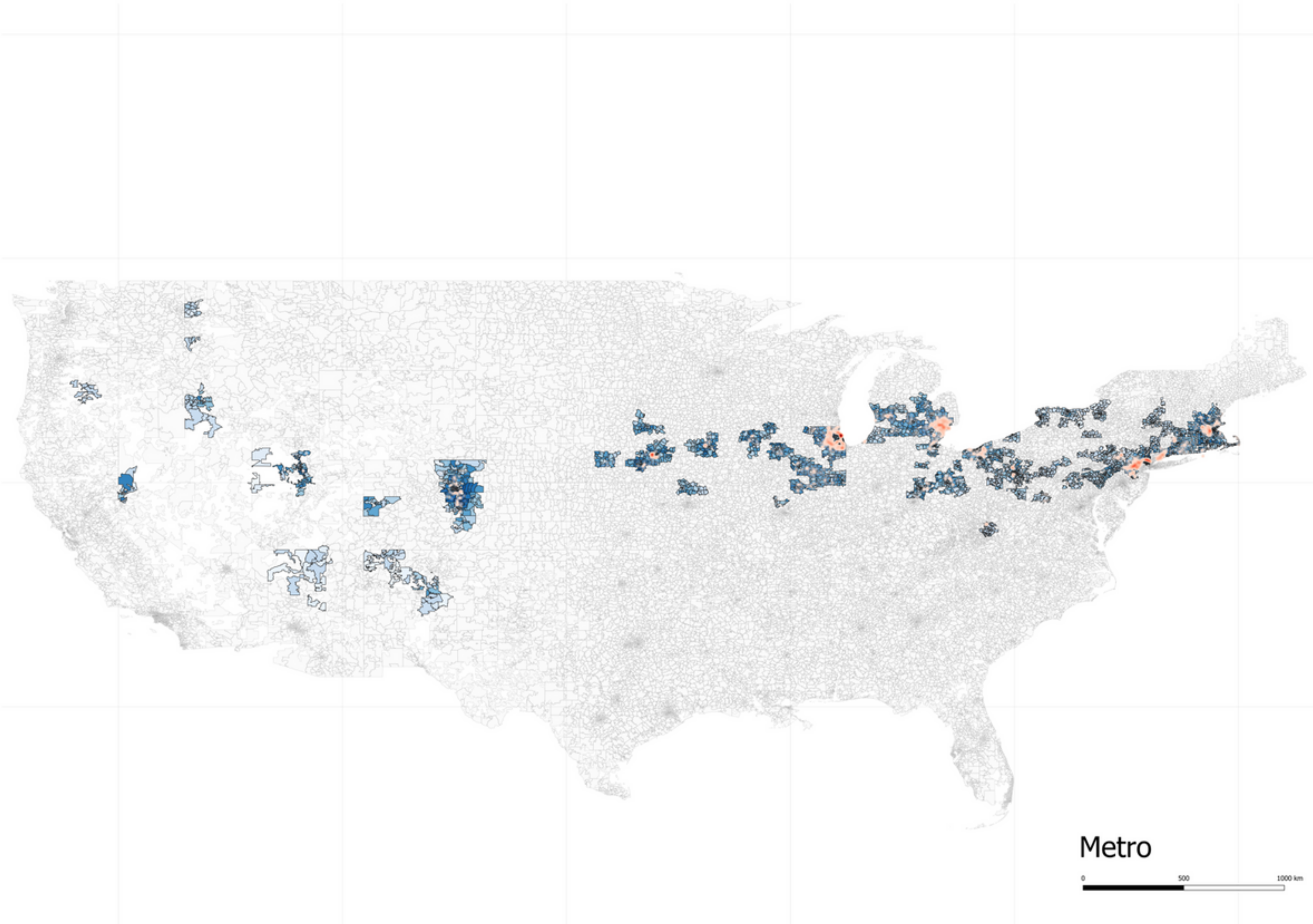

Figure 7

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Cool climate zone 5 Metro zip codes

Figure 8

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Cool climate zone 5 Micro zip codes

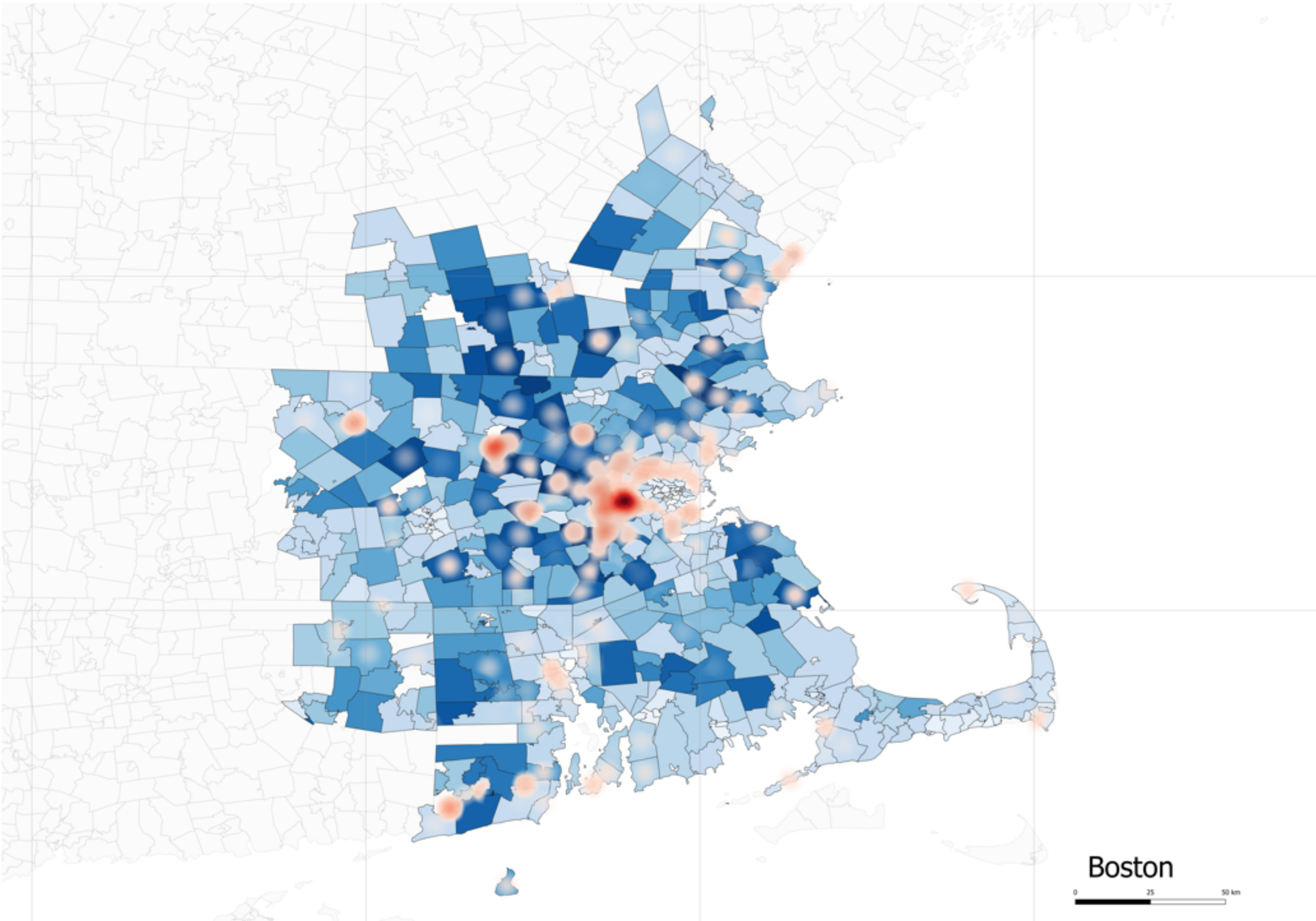

Figure 9

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Boston Metro zip codes

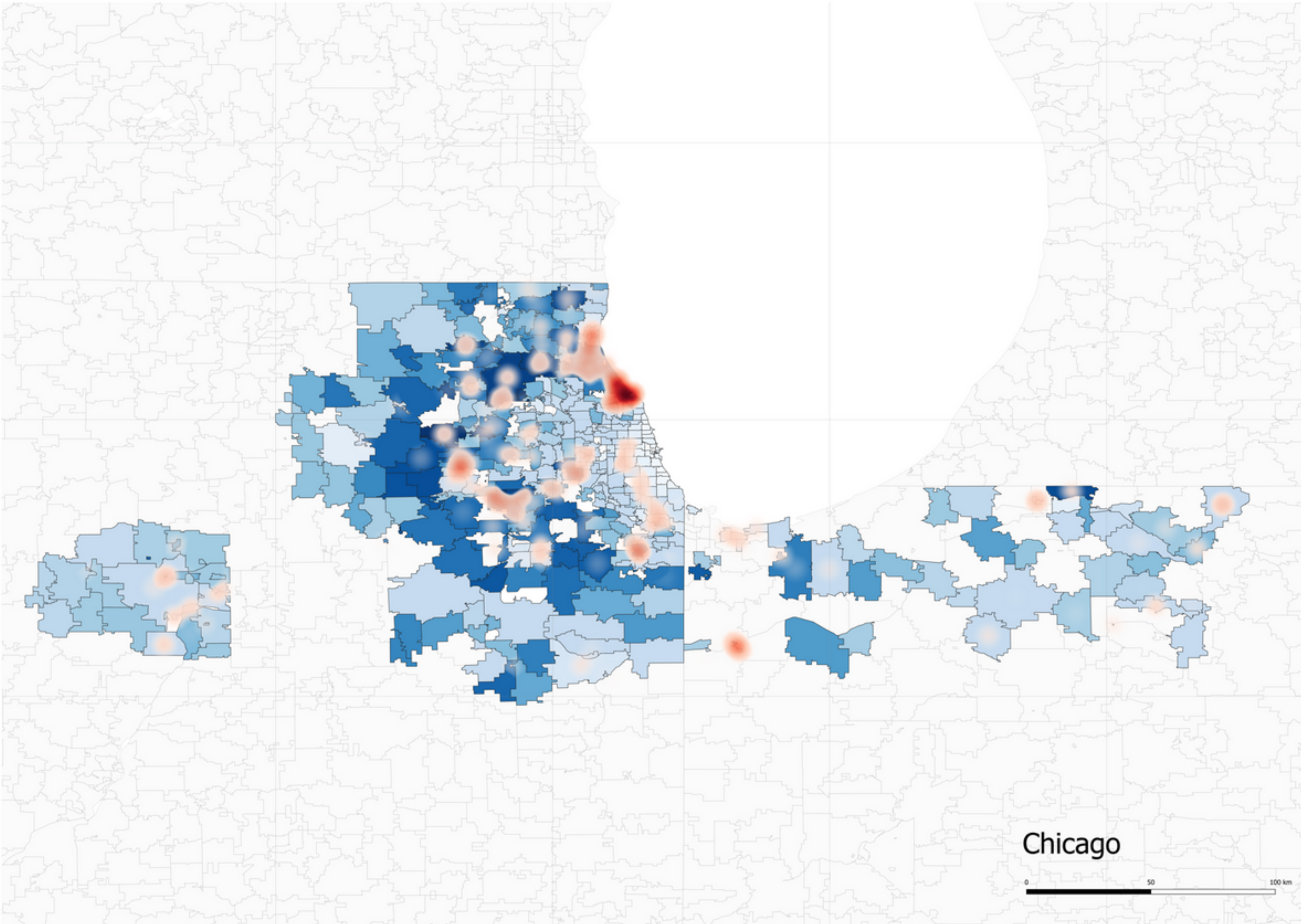

Figure 10

Heat map based on residuals extracted from a regression featuring CO_2 emissions for Chicago Metro zip codes

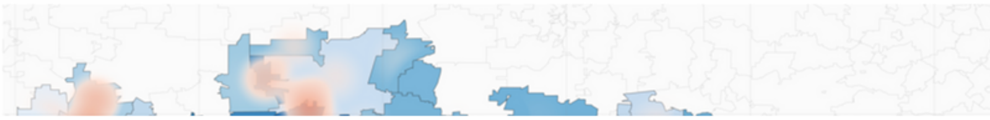

Figure 11

Heat map based on residuals extracted from a regression featuring CO_2 emissions for *Columbus* Metro zip codes

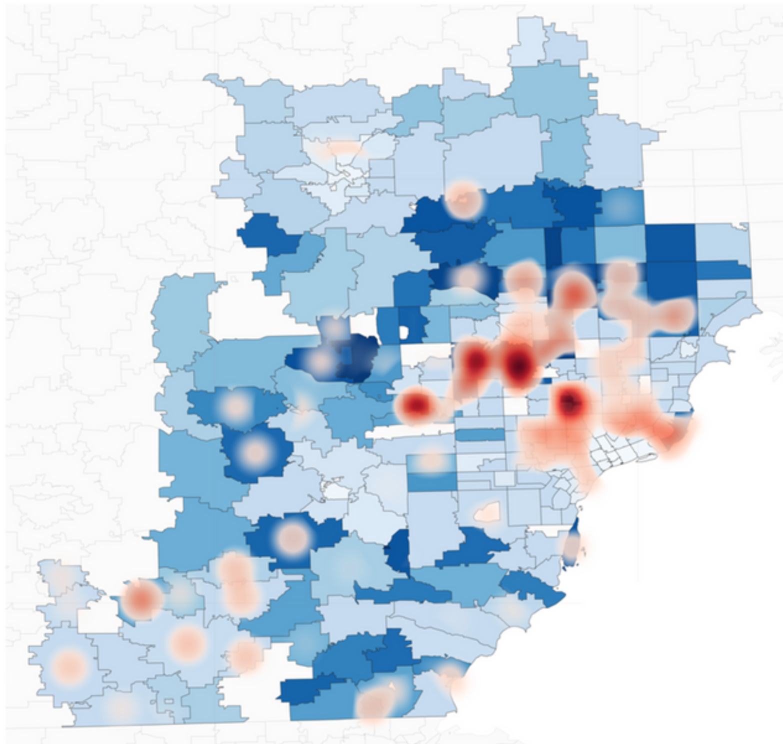

Figure 12

Heat map based on residuals extracted from a regression featuring CO_2 emissions for *Detroit* Metro zip codes