

# **The Contribution of Urban Areas to Climate Change: New York City Case Study**

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## 1. Introduction

New York is the largest city in the United States and a global center of commerce and culture. The city, which has a population of 8.25 million and average per-capita income of \$28,610, is defined by the 5 boroughs of Manhattan, Brooklyn, Queens, the Bronx, and Staten Island (Figure 1 and Table 1). The city also forms the urban core of the New York Metropolitan Area (NY Metro Area), which is composed of 23 counties in New York, New Jersey, and Connecticut and has a population of 18.8 million people (Figure 2).<sup>1</sup> In 2006, GDP was \$1.1 trillion, approximately 8 percent of total US GDP (BEA, 2008). New York City's high population density of over 10,000 people/km<sup>2</sup>, extensive public transit system, and status as a leading financial center shape patterns of greenhouse gas (GHG) emissions. In general, the city's total emissions are high but per-capita emissions are low relative to other urban areas in the United States.

As in most US cities, New York's greenhouse gas (GHG) emissions are dominated by energy-related CO<sub>2</sub> emissions since there is little agricultural or forested land within the city boundaries, and since 75 percent of the methane produced at in-city landfills and wastewater treatment plants inside the city is captured (City of New York, 2009). New York completed its first GHG emissions inventory in 2007, which revealed that more than two-thirds of city-wide emissions are associated with electricity and fuel consumption in residential, commercial, and institutional buildings. Also in 2007, New York launched PlaNYC, outlining the Mayor's vision for a more sustainable city. The plan includes the ambitious goal of reducing GHG emissions by 30 percent by 2030. In 2008, the City passed a law requiring annual updates to the emissions inventory to assess progress toward this goal.<sup>2</sup>

This case study first summarizes the findings of the city's official inventory. Next, patterns of emissions within the NY Metro Area are discussed<sup>3</sup>. Finally, some of the key considerations when designing local-scale emissions inventories are highlighted.

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<sup>1</sup> The NY Metro Area is highly integrated with several other adjacent metropolitan areas. Together, this "Combined Statistical Area," which covers the portions of New York, New Jersey, Connecticut, and Pennsylvania within commuting distance of New York City, encompasses a total population of 21.9 million and is sometimes referred to as the "Tri-State Region." This population estimate is based on the 2005-2007 American Community Survey (ACS) and covers the Combined Statistical Area of New York-Newark-Bridgeport, NY-NJ-CT-PA. Population data can be obtained from the US Census Bureau (US Census, 2006)

<sup>2</sup> City of New York, Local Laws of the City of New York for the Year 2008 – No. 22 (New York City Climate Protection Act). New York City Administrative Code §24.8. Enacted May 30, 2008.

<sup>3</sup> Vulcan was developed at Purdue University and provides high-resolution spatial data on CO<sub>2</sub> emissions for the continental United States (Gurney et al., 2008; Gurney et al., 2009). The methodology for estimating urban energy consumption and emissions is discussed in more detail in Parshall et al. (2009a), and the results are described in more detail in Parshall et al. (2009b).

**Figure 1: New York City land use (note that only part of Staten Island is shown)**



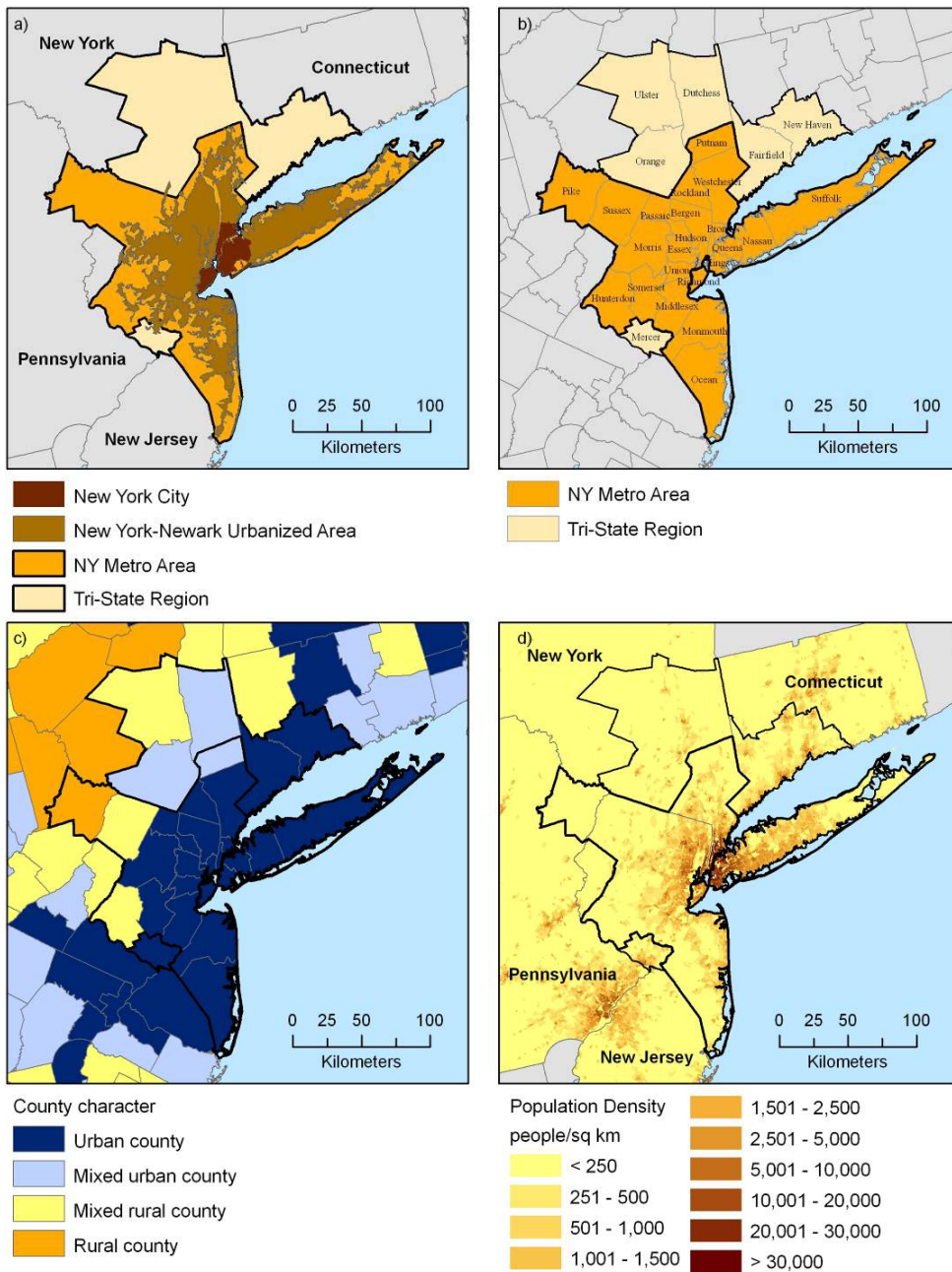
Data source: NYC Department of City Planning (2007). Map credit: Lily Parshall.

**Table 1: New York City population density and per capita income**

Borough	Population	Land area (km <sup>2</sup> )	Population density (people/km <sup>2</sup> )	Per-capita income (USD)
Bronx	1,369,859	111	12,326	16,496
Brooklyn	2,520,835	177	14,236	21,631
Manhattan	1,613,257	73	21,979	56,310
Queens	2,263,858	277	8,181	23,841
Staten Island	478,501	151	3,169	29,228
Total/Average	8,246,310	789	10,447	28,610

Notes: Population estimates are from the American Community Survey (ACS) 2005-2007; land area is based on spatial data from Tele Atlas North America (2006) available from Columbia University; per-capita income data are from the ACS 2005-2007. Average NYC income was computed by weighting each borough's per-capita income by the percent of total NYC population residing in that borough.

**Figure 2: The New York Metropolitan Area and Tri-State Region.**



*Data sources: Spatial boundaries from Tele Atlas North America, Inc. and ESRI; county character classifications from Isserman (2005); population density from US Census 2000. Map credit: Lily Parshall*

## 2 New York City GHG Emissions Inventory

New York City, like many cities in the United States, used protocols established by ICLEI-Local Governments for Sustainability as a starting point for estimating city-wide emissions, as well to develop more detailed estimates of emissions associated with government buildings and operations (ICLEI, 2008).<sup>4</sup> The current release of the NYC GHG emissions inventory reflects the most recent ICLEI Scope I protocols.<sup>5</sup>

The city-wide inventory covers emissions associated with energy consumption and solid waste within the territorial boundary defined by the 5 boroughs. In the building sector, this includes emissions associated with direct consumption of heating fuels (e.g. natural gas, distillate and residual fuel oil, kerosene, steam) and electricity (regardless of whether the electricity was produced inside the city boundaries). The majority of the emissions in this sector are CO<sub>2</sub> but the inventory does account for emissions of other greenhouse gases produced in the course of electricity production (e.g. methane, nitrous oxide). In the transportation sector, consumption of gasoline, diesel, and electricity for on-road transportation are covered in the official inventory.

Estimates for aviation and marine are included in the report, but are not part of the official inventory. In the waste sector, production of methane at in-city landfills and wastewater treatment plants is covered.

Most of New York City's solid waste is now shipped to locations outside the city (e.g., New Jersey, Pennsylvania, Virginia, and West Virginia), and most of the methane produced at in-city landfills and wastewater treatment plants is captured, so solid waste emissions account for just 1 percent of the city's total emissions.<sup>6</sup> Therefore, in our summary of New York City's findings, we focus on energy-related emissions, the majority of which are CO<sub>2</sub> emissions. In the US as a whole, approximately 82 percent of total GHG emissions are energy-related CO<sub>2</sub> emissions (US DOE, 2008). Energy-related emissions include direct fuel consumption (e.g. consumption of natural gas, fuel oil, diesel, gasoline) as well as indirect consumption of fuel used to produce electricity.

### 2.1 City-wide emissions by sector and source

New York City's total greenhouse gas emissions were estimated to be 61.5 million metric tons (MMT) of carbon dioxide equivalent (CO<sub>2</sub>e) in fiscal year 2007 (Figure 3) (City of New York, 2009). Per-capita emissions were estimated to be 7.1 metric tons of CO<sub>2</sub>e, higher than London's estimated 5.9 metric tons, but lower than estimates for Toronto (9.6), San Diego

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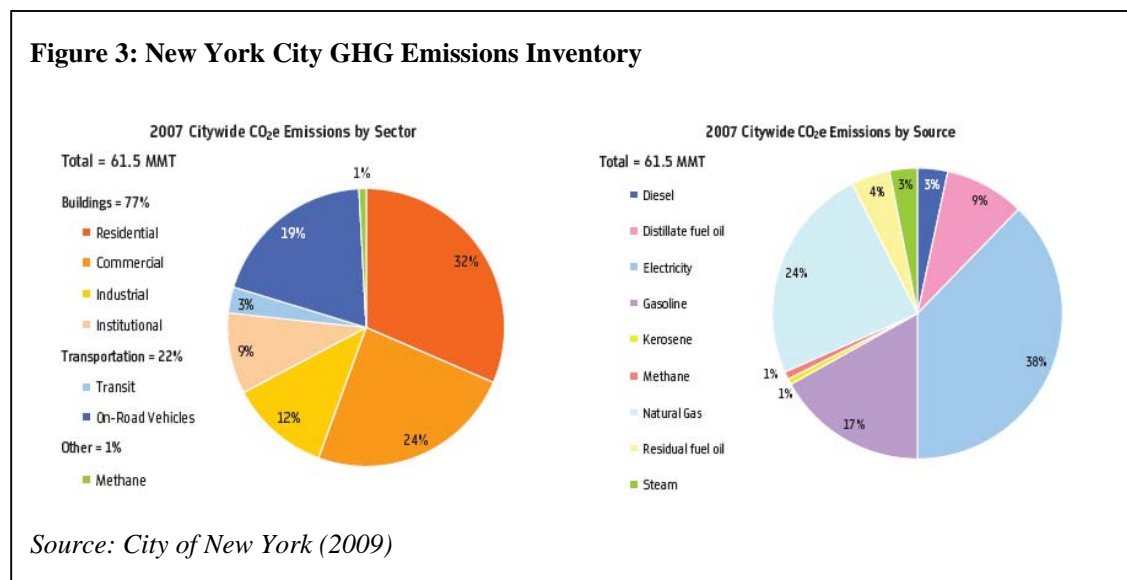
<sup>4</sup> Local authorities, with technical assistance from ICLEI's Cities for Climate Change Program (CCP), complete an inventory as part of a program that includes setting emissions reduction targets, identifying policy measures, and evaluating progress.

<sup>5</sup> Scope 1: All direct GHG emissions (with the exception of direct CO<sub>2</sub> emissions from biomass combustion). Scope 2: Indirect GHG emissions associated with the consumption of purchased or acquired electricity, steam, heating, or cooling. Scope 3: All other indirect emissions not covered in Scope 2, such as upstream and downstream emissions, emissions resulting from the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity (e.g., employee commuting and business travel), outsourced activities, waste disposal, etc (City of New York, 2009, p10).

<sup>6</sup> All of New York City's solid waste is handled by private companies. Waste is shipped to locations in several states including New Jersey, Pennsylvania, Virginia, and West Virginia.

(11.1), and San Francisco (11.2).<sup>7</sup> New York City's emissions are relatively low as a result of small dwelling sizes, high population density, an extensive public transport system, and a large number of older buildings that emphasize natural daylighting and ventilation.

Electricity accounts for about 38 percent of total CO<sub>2</sub>e emissions in New York City. The New York City electricity fuel mix is dominated by natural gas, but also includes coal, oil, nuclear, and hydropower. Natural gas is also the dominant heating fuel and direct consumption of natural gas accounts for 24 percent of emissions (City of New York, 2009).



### 2.1.1 Transportation

In the US as a whole, transportation is the largest end-use sector, accounting for 33.6 percent of total emissions (DOE, 2008). Emissions from transportation in New York were 13 MMT CO<sub>2</sub>e in fiscal year 2007, or 22 percent of total city-wide CO<sub>2</sub>e emissions, well below the average for the United States (City of New York, 2009).<sup>8</sup> Approximately 86 percent of transportation emissions are associated with on-road vehicles, with the remainder associated with public transit. New York City has the highest rate of commuting by public transit in the United States and is the only US city where more than 50 percent of the population does not drive to work (US Census, 2006). New York City's regional, multi-modal transportation system serves nearly 15 million people, with subways and buses carrying over 8.5 million riders per day, and transit ridership has been increasing at a faster rate than traffic volume (MTA, 2009; NYC DOT, 2008).

<sup>7</sup> City of New York (2007b) notes that per-capita CO<sub>2</sub>e emissions are based on reported greenhouse gas inventories with the understanding that differing methodologies and emissions sources exist. See Kennedy et al. (2009) for a comparison of 10 global cities based on a standardized methodology

<sup>8</sup> Although New York City's official inventory did not include greenhouse gas emissions from aviation and shipping, emissions from aviation have been estimated at 10.4 million metric tons while emissions from transportation of freight by water have been estimated at 6.2 million metric tons (City of New York, 2007a).

### **2.1.2 Buildings**

Residential and commercial buildings each account for a larger share of emissions than transportation, and, overall, buildings account for 77 percent of greenhouse gas emissions (City of New York, 2009). Since buildings account for the majority of emissions, this sector is likely to be the key focal point for emissions reduction policies in New York City.

Of total building emissions, residential buildings account for the largest share (41.6 percent), followed by commercial buildings (31.2 percent), industrial buildings (15.6 percent), and institutional buildings (11.7 percent). Note that these figures include demand for electricity as well as direct consumption of heating fuels.

The share of building-sector emissions in New York City is larger than in the US as a whole both because of reduced transportation-sector emissions and because of New York's large amount of residential floor space and energy-intensive commercial sector. New York City's nearly one million buildings include over 316 million square meters of residential floor space, of which more than 30 percent is one and two family homes (New York City Department of City Planning, 2008). The city's more than 171 million square meters of commercial floor space is dominated by private services-producing industries with high energy intensity (demand per square meter of floor space) (New York City Department of City Planning, 2008; BEA, 2008).

## **2.2 City government emissions**

City government emissions are the portion of city-wide emissions attributable to government operations – e.g., emissions associated with government buildings, streetlights and traffic signals, the municipal vehicle fleet, and city landfills, etc. Cities have more direct control over emissions associated with their own operations, so it is often easier to reduce these emissions than to influence city-wide emissions. For this reason, New York City has set a target of a 30 percent reduction in government operations emissions by 2017 (versus 2030 for a 30 percent city-wide reduction) (City of New York, 2007a).

Greenhouse gases emitted as a result of government operations were 4.3 MMT of CO<sub>2</sub>e in fiscal year of 2007, representing approximately 7 percent of the city-wide total, and a 5.6 percent increase over the 2006 total (City of New York, 2009). Similar to the city-wide results, buildings account for the vast majority of city government emissions (63 percent). The city's municipal vehicle fleet accounts for 8 percent of the total (City of New York, 2009). New York City attributes the increase in emissions between 2006 and 2007 to higher energy demand in buildings and methane leakage from wastewater plants, which outweighed decreases associated with a cleaner electricity supply and milder weather (City of New York, 2009).

## **2.3 Trends and policies**

New York City's 2007 city-wide inventory showed that CO<sub>2</sub>e emissions decreased by 2.5 percent between 2005 and 2007 (City of New York, 2009) (Table 2)<sup>9</sup>. Although energy consumption increased between these two years as a result of population growth and greater electricity and heating fuel demand, the carbon intensity of the electricity supply decreased

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<sup>9</sup> The base year, 2005, was chosen to align with the larger framework of PlaNYC (City of New York, 2007a)



when two efficient new power plants were brought on line in 2006, displacing electricity generated from less efficient plants with higher CO<sub>2e</sub> coefficients (City of New York, 2009). This change alone reduced emissions by approximately 3.2 MMT (5 percent reduction); milder winter and summer weather conditions in 2007 as compared with 2005 also contributed to the reduction<sup>10</sup>.

**Table 2: New York city-wide energy-related GHG emissions**

<b>Sector</b>	<b>2005</b>	<b>2007</b>	<b>% change</b>
Residential buildings	19,273,305	19,284,241	0.1%
Commercial buildings	15,875,854	14,824,825	-6.6%
Institutional buildings	7,506,849	7,111,314	-5.3%
Industrial buildings	6,228,463	5,776,417	-7.3%
On-road vehicles	11,500,592	11,913,542	3.6%
Transit	2,070,742	1,955,937	-5.5%
Streetlights/traffic signals	162,377	141,397	-12.9%
<b>Total</b>	<b>63,052,184</b>	<b>61,464,398</b>	<b>-2.5%</b>

*Source: Adapted from City of New York (2009).*

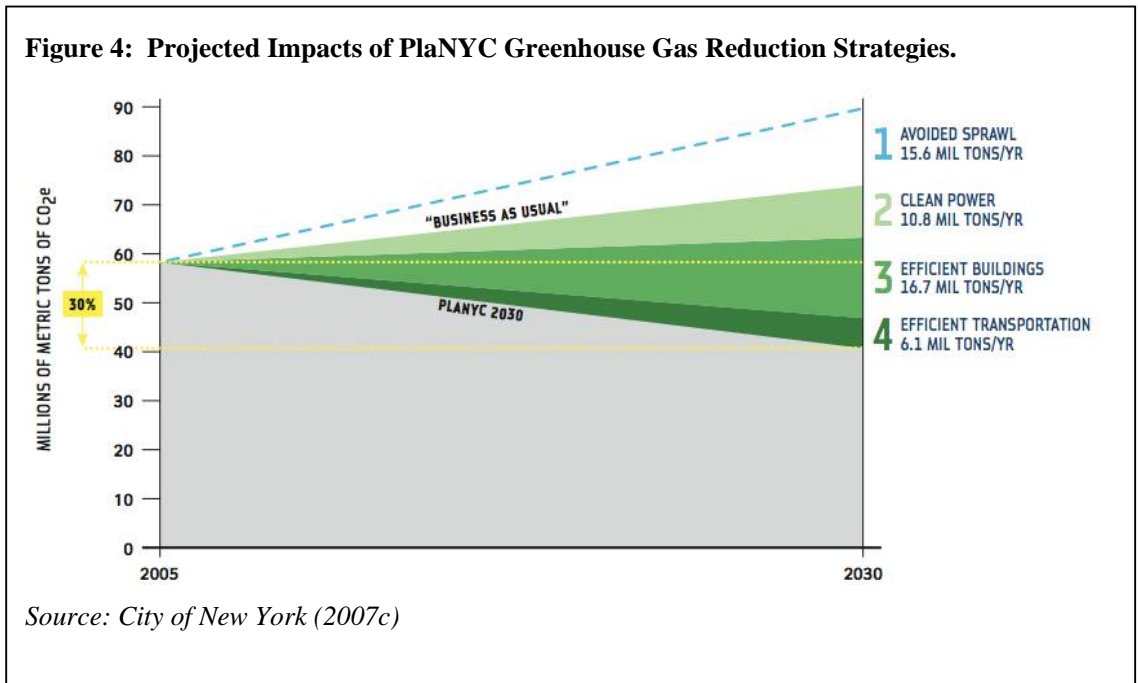
Government operations emissions increased by 5.6 percent between fiscal year 2006 and 2007 as a result of an increase in electricity and heating fuel consumption in city buildings as well as leakage of methane gas from wastewater treatment plants experiencing mechanical problems (City of New York, 2009).<sup>11</sup> The New York City Council recently enacted Local Law 86 in 2005, which requires most new city-owned and city-funded buildings to implement the Leadership in Energy and Environmental Design (LEED) Silver Certification standards, one measure aimed at reducing emissions from government operations.<sup>12</sup> The law has stimulated substantial interest in green buildings and helped push high-end residential and commercial developments in New York City to consider LEED certification regardless of whether city funding is involved. Presently, there are 27 LEED certified buildings in New York City. However, the actual energy performance of LEED buildings relative to new construction in general has been questioned, partly because energy efficiency is just one aspect of LEED's environmental standards (Hinge and Winston, 2009).

<sup>10</sup> Heating degree days (HDD) and cooling degree days (CDD), which reflect the demand for energy needed to heat or cool a home or business, decreased by 0.6 percent and 17.7 percent respectively from 2005 to 2007 (City of New York, 2009).

<sup>11</sup> The base year for analysis, FY 2006 (July 1, 2005 – June 30, 2006) was chosen because the City's financial records are fiscal year-based and fiscal year 2006 was the most recent complete fiscal year (City of New York, 2007a). The primary reason for the increase in City government operation emissions is the 2.6percent increase in electricity consumption. Almost a quarter of this growth reflects the operation of additional space as new City buildings came on line or additional ones were leased. Over 1percent of electricity consumption can be attributed to more electricity used per employee. Finally, the City collected more accurate building data for fiscal year 2007 building electricity consumption data compared to fiscal year 2006. Also due to improved data, emissions from the consumption of natural gas and fuel oil for heating City buildings and creating hot water increased 1.9percent (City of New York, 2009).

<sup>12</sup> LEED was established in 1998 by the US Green Buildings Council and requires a variety of criteria as prerequisites with various additional credits earned toward different levels of certification.

**Figure 4: Projected Impacts of PlaNYC Greenhouse Gas Reduction Strategies.**



The city is also pursuing a variety of measures aimed at meeting the city wide goal of reducing emissions in 2030 by 30 percent compared to a 2005 baseline emissions level (Figure 4). CO<sub>2</sub> reduction initiatives fall into three primary areas:

- Upgrading the local power supply by replacing inefficient power plants with more advanced technologies and promoting the deployment of “clean” distributed generation and renewable power sources around the city. For example, in 2008 the City began accepting bids to install 2 MW of solar panels on local government buildings, and in 2009, the Mayor’s office hired a consultant to develop a 10-year plan for increasing the use of peak load management strategies in commercial buildings around the city.
- Reducing energy consumption in local buildings by imposing more aggressive energy codes for new buildings and promoting energy efficiency measures in existing buildings. One proposal currently under consideration requires the owners of buildings larger than 50,000 square feet to audit their buildings and implement any energy efficiency retrofits with a payback period of less than five years.
- Reducing transport-related emissions through the expanded use of public transport, promoting fuel switching in private vehicles and taxis, and decreasing the CO<sub>2</sub> intensity of local transport fuels. Some of the Mayor’s proposals, such as his support for congestion pricing in midtown Manhattan and a hybrid taxi program, have run into opposition from state officials and the courts and are currently being revised. Another initiative aimed at promoting B20 and B50 biodiesel use by city-owned fleet vehicles is moving ahead at a rapid pace.

Given the city’s emissions profile, efforts promoting more energy efficient buildings are expected to deliver approximately half of these total emission reductions.

An interesting idea promoted by PlaNYC is the notion that the city's anticipated 900,000 person population increase by itself results in a net global carbon reduction of approximately 15.6 million tons per year, because the average New Yorker emits far less greenhouse gases per year than the average American (City of New York, 2007c).

Another noteworthy aspect of the PlaNYC initiative is its explicit acknowledgement of the relatively weak nature of the city's energy planning powers. Because most energy planning and regulatory control powers are in federal and state government hands (Hammer, 2009), PlaNYC is replete with references to the City's need to partner with others to ensure its key goals are attained. The plan also puts forth several different proposals designed to enhance local energy governance, such as by arguing for more direct control over energy efficiency funding traditionally controlled by the state. As of mid-2009, these calls for the devolution of certain energy planning control powers and the imposition of new fees designed to support City of New York efforts at energy efficiency had failed to find much support among state legislators.

### **3 Patterns of emissions within the New York Metropolitan Area**

Since patterns of emissions are influenced by regional processes (e.g., commuting from suburban areas, regional availability of energy sources), it is important to situate New York City's emissions in a regional context. The Vulcan data product, a high-resolution gridded CO<sub>2</sub> emissions inventory, was used to analyze emissions in the New York Metropolitan Area (NY Metro Area) as part of a larger study analyzing patterns of urban energy consumption across the United States (Parshall et al., 2009b).<sup>13</sup> The NY Metro Area is comprised of counties that are economically integrated with New York City's urban core. The analysis covered heating fuels (natural gas and LPG, distillate and residual fuel oil) and transport fuels (gasoline and diesel).<sup>14</sup> From a greenhouse gas emissions accounting perspective, IPCC Scope 1 CO<sub>2</sub> emissions associated with stationary combustion in the energy sector were covered, but utility-consumed fuel for electricity/heat generation was excluded.

The overall density of people and economic activity in the NY Metro Area translates into higher-than-average total CO<sub>2</sub> emissions relative to other urbanized regions. On the other hand, per-capita emissions in the NY Metro Area's 19 urban counties are more than 25 percent lower, on average, than per-capita emissions in all US urban counties (Figure 5). In the 5 counties of New York City, per-capita emissions are less than 50 percent of the US

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<sup>13</sup> Vulcan consolidates data from a wide variety of point, non-point, and mobile sources and quantifies these data in their "native" resolution (geocoded points, roads, counties) and on a regular 100-km<sup>2</sup> grid over the conterminous United States (Gurney et al., 2008; Gurney et al., 2009). A county resolution version of Vulcan was used to analyze patterns of emissions within the NY Metro Area. US counties were classified as urban or rural using a classification system developed by Isserman (2005)

<sup>14</sup> The study focused on CO<sub>2</sub> emissions associated with direct final consumption of fossil fuels, the portion of total emissions for which consistent, consumption-based estimates could be established for both energy and emissions. In the case of these fuels, the spatial location of energy consumption is the same as the spatial location of combustion, and thus CO<sub>2</sub> emissions. The electricity sector was excluded because of the difficulty of allocating power plant emissions to the location where electricity was consumed, a key methodological challenge for consumption-based inventories. Brown et al. (2008) computed partial carbon footprints for the 100 largest US metropolitan areas. This is one of the few studies that estimates emissions associated with electricity consumption across a large number of urban areas.

urban average (Parshall et al., 2009b). The NY Metro Area's direct fuel consumption was estimated to be 125.4 GJ per capita compared with 78.0 GJ per capita in New York City (Table 3) (Parshall et al., 2009b). Associated CO<sub>2</sub> emissions were estimated at 7.8 tons per capita and 4.8 tons per capita respectively.

**Table 3; Average per-capita fuel consumption and CO<sub>2</sub> emissions for subsets of counties in the NY Metro Area compared to the United States**

Category (# of counties)	Buildings and Industry		Transportation	
	Energy Consumption (GJ/capita)	Emissions (Mt CO <sub>2</sub> /capita)	Energy Consumption (GJ/capita)	Emissions (Mt CO <sub>2</sub> /capit a)
Rural counties (1)	35.1	2.2	121.2	8.2
Mixed rural counties (2)	50.3	3.0	98.5	6.6
Mixed urban counties (1)	32.9	2.2	238.7	15.9
Urban counties (19)	57.3	3.2	56.2	3.8
<b>NY Metro Area (23)</b>	<b>54.7</b>	<b>3.1</b>	<b>70.7</b>	<b>4.7</b>
Rural counties (1767)	136.7	7.5	147.3	9.9
Mixed rural counties (1013)	143.8	8.0	103.4	7.0
Mixed urban counties (145)	89.4	4.8	86.2	5.8
Urban counties (157)	86.5	4.7	74.0	5.0
<b>United States (3108)</b>	<b>133.8</b>	<b>7.4</b>	<b>125.8</b>	<b>8.5</b>
<b>New York State (62)</b>	<b>56.9</b>	<b>3.3</b>	<b>91.5</b>	<b>6.1</b>
<b>Tri-State Area (29)</b>	<b>53.2</b>	<b>3.0</b>	<b>73.1</b>	<b>4.9</b>
<b>New York City (5)</b>	<b>54.1</b>	<b>3.2</b>	<b>23.9</b>	<b>1.6</b>

*Data sources: Vulcan data product for energy and emissions data, US Census 2000 for population data.*

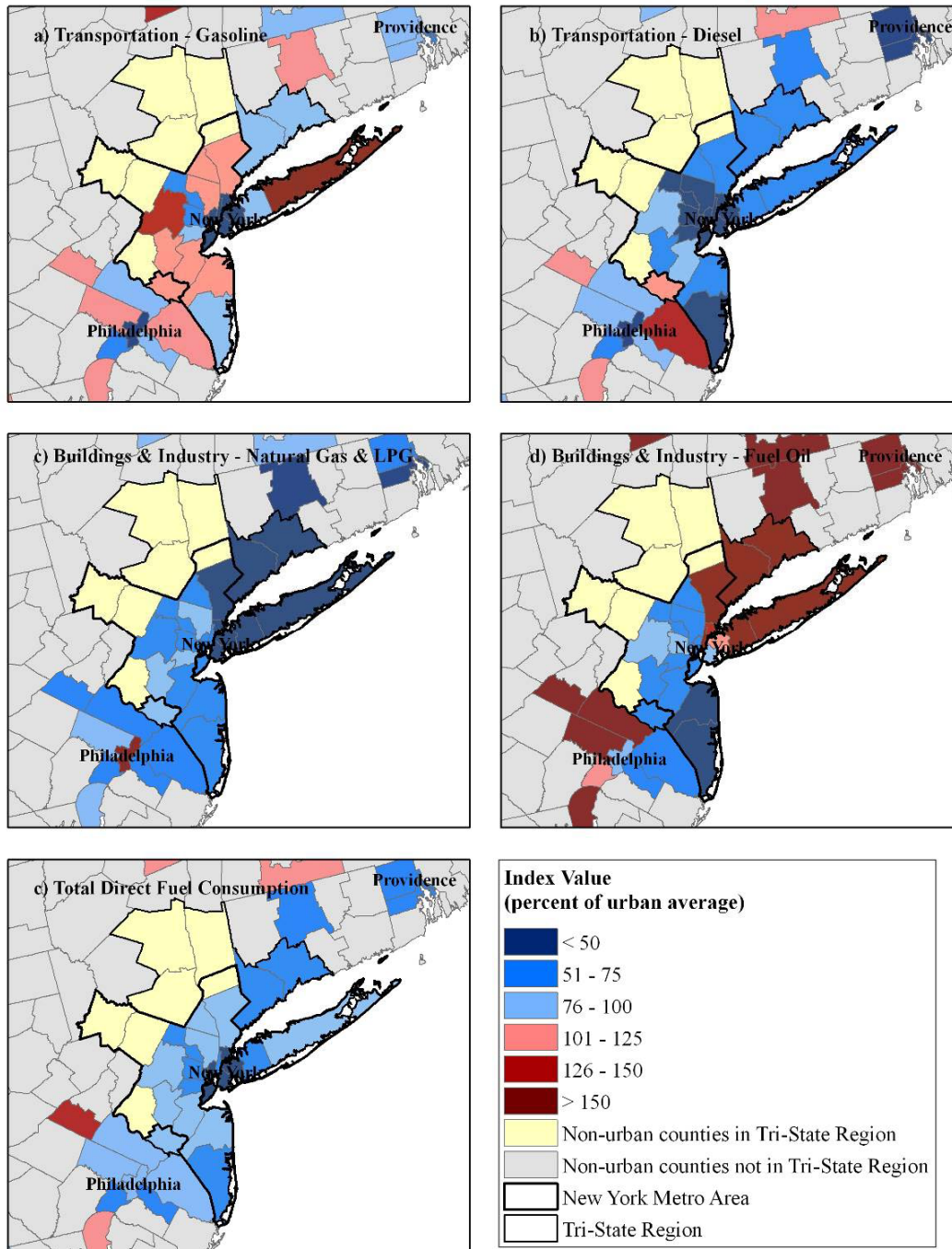
### 3.1 Transportation

Reliance on public transit within the 5 boroughs of New York City is reflected in low per-capita gasoline consumption (< 50 percent of the US urban average). Outside the city, regional commuter railroads and bus systems serve densely populated suburbs, but gasoline-powered personal vehicles are the primary mode of transportation for most people; this is reflected in higher per-capita gasoline consumption outside the core (in many suburban counties in the NY Metro Area, consumption is higher than the US urban average). This finding is consistent with an earlier study of gasoline consumption that found, in 1980, the typical resident of the New York Tristate Region used 335 gallons of gasoline per person, whereas a resident of New York City (5 boroughs) used 153 gallons per person, and a resident of New York County (Manhattan) used 90 gallons per person (Newman and Kenworthy, 1989).

New York City has the largest public transit system in the United States and is one of the few American cities where the majority of the population relies on public transportation to travel to work (City of New York, 2007). Whereas nationally, 90 percent of households own one or more private vehicles, in New York City only 44 percent own a car (City of New York, 2007). Reliance on public transit and population density are interrelated in that high

population and job density increase the viability of and demand for public transit at the same time that effective public transit can increase population density.

**Figure 5; CO2 emissions associated with direct fuel consumption in urban counties in the New York Tri-state Region. Note that the urban average is the average across the 157 urban counties in the continental United States**



Data source: Vulcan data product. Map credit: Lily Parshall

In general, older US cities that developed on the basis of manufacturing and trade, and before the invention of the automobile, have higher population density, more effective public transit systems, and lower per-capita transportation emissions compared with newer cities<sup>15</sup>. In the case of New York City, some specific policies encouraged the concentration of jobs in Manhattan's Central Business District (CBD). For example, Manhattan zoning regulations were designed to encourage mixed land use and a high floor area ratio (FAR) in the CBD, which supported transit-oriented growth by generating demand for trips throughout the day and evening (Bertraud et al., 2009).<sup>16</sup> Also, since there is limited parking space along Manhattan streets, most cars are parked in expensive private lots, rather than along streets (Bertraud et al., 2009).

Counties that are part of the NY Metro Area, but outside of the urban core of New York City, vary widely in their gasoline consumption, with some counties exceeding the US urban average, and other counties falling below the average (see Figure 5a). These differences may be related to the share of the population commuting to New York City and/or other urban centers, accessibility of commuter railroads and buses, land use mix, and population density, among other factors. Further research is needed to understand how various factors may influence gasoline consumption in different parts of the NY Metro Area.

Whereas the primary end use for gasoline is personal transportation, the primary end use for diesel fuel is freight, with diesel also used in public transit. Overall, diesel, which has slightly higher CO<sub>2</sub> emissions per unit of fuel consumed, accounts for a relatively small share of total transportation emissions in the NY Metro Area.<sup>17</sup> Throughout the NY Metro Area, per-capita diesel consumption is lower than the US urban average, and New York City's 5 boroughs consume less than 50 percent of the US urban average for diesel (see Figure 5b). This may be related to higher overall population density and thus fewer freight kilometers driven per person.

### 3.2 Buildings and industry

Per-capita emissions from buildings and industry are lower than the US average, but unlike in the transportation sector, urban counties have higher per-capita emissions compared with suburban and rural counties within the metro area (see Table 2). Buildings and industry are grouped together into a single category because the data did not allow for separation between residential, commercial, and industrial buildings.<sup>18</sup> Since estimates of per capita emissions are obtained by dividing total emissions from buildings and industry within a particular county by the population of the county, emissions associated with the commercial and industrial sectors are allocated to the local population. New York City has a greater amount of commercial and industrial floor space, per capita, than other counties in the NY Metro Area, and this translates into higher per capita emissions. Also, commercial floor space tends to require more energy

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<sup>15</sup> Other examples of older cities with high population density (> 1000 people/km<sup>2</sup>) and low per-capita gasoline consumption include Philadelphia, Washington D.C., and Boston (Parshall et al., 2009b). See Kim (2000) for a discussion of how historical economic development and timing of urban expansion have affected urban population size and density.

<sup>16</sup> FAR is the ratio of building area (i.e., total floor space area) to plot area

<sup>17</sup> In US urban counties overall, diesel accounts for approximately 17percent of on-road transportation fuel consumption and 18percent of on-road transportation CO<sub>2</sub> emissions (Parshall et al., 2009b).

<sup>18</sup> Emissions from Vulcan can be reported by sectoral (residential, commercial, industrial, transportation) and/or fuel divisions (coal, oil, and natural gas). Rather than employ a dataset with sectoral categories, a dataset where emissions were disaggregated by sub-fuel, but not by sector, was employed. Sub-fuel data were required to convert from emissions to energy units, but sub-fuel data disaggregated by sector were not available at the time of the analysis (Parshall et al., 2009a)

per unit area than residential floor space. Other factors that affect per capita emissions include fuel type, climate, building stock, energy prices, and income. In general, the NY Metro Area's high energy prices would be expected to have a downward influence on consumption whereas relatively high income levels would be expected to have an upward influence on consumption. Each of the other factors is discussed in detail below, but further research is needed to understand how these factors interact with one another.

**Fuel type:** Only emissions associated with direct fuel consumption were covered by the analysis of buildings and industry. The NY Metro Area consumes a mix of natural gas and fuel oil to meet demand for space heating and hot water<sup>19</sup>. Since fuel oil has higher CO<sub>2</sub> emissions per unit of energy than natural gas, consumption of fuel oil has an upward influence on per capita emissions. Nassau and Suffolk counties on Long Island are examples of counties with relatively high fuel oil consumption (see Figure 5; county names are included on Figure 2).

**Climate:** New York City has fewer heating degree days compared with inland and upstate portions of the NY Metro Area, both as a result of the moderating effect of a coastal climate and the urban heat island. This is expected to have a downward effect on per capita consumption of fuel for space heating, but little effect on demand for hot water.

**Building stock and heating equipment:** New York City has more attached, multi-family housing. Since less heat is lost through the walls in this type of housing, this would be expected to have a downward effect on per capita consumption for space heating. On the other hand, much of the building stock in New York City and the NY Metro Area is older than in other parts of the United States and is therefore more likely to have older, less efficient heating systems. This would be expected to have an upward effect on per capita consumption for space heating. Finally, the size of the average residential unit in New York City is smaller than in other parts of the NY Metro Area. This would be expected to have a downward effect on per capita demand for space heating.

### 3.3 Comparisons with other studies

Using the Vulcan data product, on-road transportation emissions were estimated to be 1.6 tons per capita in New York City (5 boroughs) and building and industry emissions to be 3.2 tons per capita in 2002. These numbers agree well with the results of New York City's GHG emissions inventory and with the New York City findings in a recent study comparing emissions in 10 global cities (City of New York, 2009; Kennedy et al., 2009). Based on data in New York City's official emissions inventory, on-road transportation emissions were estimated to be 1.4 tons per capita in 2007 (City of New York, 2009). Building and industry emissions were estimated to be 5.7 tons per capita, including electricity, of which 2.8 tons per capita were associated with heating fuels (not including steam) (City of New York, 2009). The Vulcan estimate is 14 percent higher than this, a reasonable discrepancy given the differing methodologies and baseline years. But, in Vulcan, the share of fuel oil (versus natural gas) consumption is higher than in the official NYC inventory.

Another recent study compared emissions in the 100 largest metropolitan areas in the United States (Brown et al., 2008). This study estimated CO<sub>2</sub> emissions associated with residential heating fuel to be 0.4 tons of carbon per capita, which is equivalent to 1.6 tons of CO<sub>2</sub> per

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<sup>19</sup> In Manhattan, there is also a district steam system serving approximately 1800 customers, but this was not included in our analysis. Also, some natural gas and fuel oil is consumed in industrial production, and natural gas is also used for cooking. Fuel demand for industrial production and cooking is likely to be relatively small compared with demand for space heating and hot water in the NY Metro Area.

capita. In New York City, the residential sector accounts for approximately 52 percent of heating fuel consumption. Assuming a similar ratio for the NY Metro Area, total heating fuel emissions might be approximately 3.2 tons per capita, an estimate that agrees well with the Vulcan-based estimate of 3.1 tons per capita. Transportation estimates were not as close: Brown et al. (2008) estimate 3.0 tons per capita, and we estimate 4.7 tons per capita. A large part of this discrepancy is likely explained by the exclusion of non-highway transportation in Brown et al. (2008).

## 4 Conclusions

In New York City, per-capita emissions are already below emissions in many other cities in developed countries, and the city has ambitious goals with respect to further reductions. The city's emissions inventories have helped identify the largest sources of emissions, and have served as a catalyst for targeted policy proposals.

Comparing the urban core with suburban portions of the New York Metropolitan Area confirms the importance of New York City's public transit system in reducing per-capita emissions in the transportation sector. On the other hand, building sector emissions are higher in some portions of the urban core compared to the surrounding region as a result of higher commercial activity. New York City's commercial sector serves the wider metropolitan area, raising questions about how responsibility for emissions associated with economic activity should be allocated across localities.

A range of different methodological approaches, accounting systems, urban boundaries, and datasets have been employed to study urban consumption patterns, with continuing disagreement on what portion of global emissions should be attributed to cities and/or urban households and how best to support urban energy and climate initiatives through local inventories. New York City's official GHG emissions inventory covered emissions associated with energy consumption and waste production within the city's territorial boundary, following ICLEI's protocols. An advantage of ICLEI's approach is that local authorities complete the inventory for their own jurisdictional area using a consistent approach. Through the process of completing an inventory, cities gain detailed knowledge of their own emissions and become invested in local emissions reduction measures. On the other hand, it can be difficult to compare participating localities because they have some latitude in their choice of data, baseline year, and level of detail, and are free to decide whether and how to disseminate inventory data and results<sup>20</sup>.

In our analysis of urban energy consumption and related CO<sub>2</sub> emissions across the United States, we identified a number of factors that are important to the design of local-scale inventories. These include consistency of data, a spatial resolution that is appropriate from the perspective of local energy governance, a coherent accounting framework, and the inclusion of attributes such as population and local character (e.g. urban versus rural) that are important when trying to make comparisons across cities (Parshall et al. 2009a). Development of internationally recognized standards and mandatory reporting protocols for local-scale energy and emissions inventories is needed to provide credible and consistent data on local

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<sup>20</sup> ICLEI (2008) contains protocols for conducting local inventories, with the intention of providing an internationally recognized set of standards comparable to standards for national inventories developed by the International Panel on Climate Change (IPCC) (ICLEI, 2008). The document includes a careful treatment of boundary issues and energy accounting for local-scale inventories.



emissions, and to support local climate mitigation. Robust comparisons across cities could help to identify low-energy and low-carbon pathways in a range of different types of urban areas around the world.

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