Framework for Achieving Low-Carbon Cities

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Disclaimer

This report presents the results of a one-semester University project involving 11 students from The Department of Civil and Environmental Engineering, Chemical Engineering, Engineering and Public Policy and the Tepper School of Business, at Carnegie Mellon University. ***AS A STUDENT PROJECT, IT HAS NOT BEEN SUBJECTED TO THE CRITICAL REVIEW PROCESS TYPICAL OF OFFICIAL PUBLICATIONS.*** In completing this project, students contribute skills from their individual disciplines and gain experience in solving problems that require interdisciplinary cooperation. The project is managed by graduate students and monitored by faculty advisors. An advisory panel of academic and industry experts provides suggestions, information, and expertise.

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This project was conducted by students from the Department of Civil and Environmental Engineering, Chemical Engineering and the Tepper School of Business at Carnegie Mellon University.

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1. Executive Summary

In 2008, the Pittsburgh Climate Initiate (PCI) completed Pittsburgh's first climate action plan and inventory of greenhouses gases. As a result, Pittsburgh joins an elite group of dozens of other local governments that are taking initiatives to make their cities more sustainable.

We commend the City, PCI, and their partners for committing resources to improving Pittsburgh's viability. Their generous and progressive initiative not only enhances the sustainability of our community but does so for communities everywhere.

The purpose of this project was to review Pittsburgh's 2003 greenhouse gas inventory and 2008 climate action plan. Our objectives were to provide quality assurance of the original inventory and action plan and to recommend improvements for future inventories and action plans.

Our review of the existing 2003 inventory suggests:

- The 2003 inventory estimates are within 3% of estimates derived from public data;
- The electricity emissions factor used in the 2003 inventory is higher than published estimates;
- Natural gas use cited in the 2003 inventory is lower than estimates derived from public data;
- The 2003 inventory's geographic and jurisdictional boundary includes the City government and the greater community within the City. This boundary excludes some carbon-intensive activities that are directly or indirectly associated with Pittsburgh, such as emissions under Allegheny County's jurisdiction. For example, extending the boundary to including public transit and air transportation increases emissions by 20%. A more inclusive boundary may lead to a more appropriate inventory and more effective action items;
- The City used the 'Clean Air Climate Protection' tool published by ICLEI to prepare the 2003 inventory. The ICLEI software is a common standard for inventorying emissions from cities. Our review of the ICLEI software indicates that it provides adequate accounting capabilities but it lacks critical data collection guidance, planning, and quality assurance features.

We compared Pittsburgh's emissions per capita to those published for twelve other cities. A Pittsburgher's GHG emissions ranked 3rd highest, twice that of a Chicagoan's and three times that of a New Yorker's. A Pittsburgher's transportation emissions were relatively low; however, Pittsburghers demonstrated the highest commercial sector emissions.

Intercity comparisons provide quality assurance, enhance quantification, bound reduction goals, identify common action items, and highlight emission reductions strategies. However, cities and sustainability organizations have yet to coordinate when preparing inventories and action plans.

The City, PCI, and partners can demonstrate leadership by coordinating with ICLEI and other cities to develop (1) meaningful, consistent standards for inventory boundaries, (2) guidelines for data collection and transparency, (3) quality assurance standards, and (4) intercity comparison metrics. We demonstrate how to meet some of these recommendations herein.

To improve future inventories, we recommend the City, PCI, and partners (1) quality check data using alternative sources, such as those documented in this report (2) compare per capita emissions for Pittsburgh to those published by other cities for quality assurance (3) expand the inventory boundary to reflect all carbon-intensive activities directly and indirectly associated *with the City, which may necessitate partnering with the County and municipal authorities and (4) improve the transparency of proprietary fuel use data, such as obtaining permission to publish aggregated utility billing records data.*

Our review of the climate action plan suggests:

- The action items documented in Pittsburgh's 2008 action plan are relatively diverse and exhaustive, reflecting similar action items considered by other cities;
- The 2008 climate action plan lacks analytical rigor. Costs and effectiveness are not quantified, making financial planning, performance tracking, and implementation difficult;
- The 2008 action plan does not assign responsibilities or establish measurable objectives. As a result, a limited number of recommendations are actionable.

We developed tools and methods to improve the analytical rigor associated with climate action plans. We quantified the cost and effectiveness of 38 of the 122 action items published in the 2008 action plan. We limited our study to non-behavioral items. Scenario analysis was used to evaluate the costs and effectiveness of various program designs.

Results indicate that achieving GHG reductions requires significant initial capital: approximately \$1M to \$10M for every percent reduction depending on program scale and scope. However, long-term savings are substantial if the program is properly designed, with the 20-year internal rate of return for many CAP programs exceeding 100%.

A majority of low-cost, effective action items are outside of the City's immediate jurisdiction. Thus programs limited to action items within the City jurisdiction can be more costly and less effective than programs that encompass community-wide emission reduction opportunities. Some action items demonstrate near immediate cost savings, which suggest that creative financing may reduce the initial capital required to achieve reductions.

To improve future climate action plans, we recommend the City, PCI, and partners (1) publish an actionable long-term program with measurable goals, costs, and responsibilities (2) quantify all action items by making assumptions necessary to explicitly document costs and effectiveness (3) prioritize action items based upon initial cost, lifetime cost, effectiveness, and feasibility (4) match recommendations with costs, goals, and responsibilities (5) be explicit about methods and sources (6) collaborate with other cities to enhance quantification and prioritization (7) review per capita emissions from other cities to set reasonable goals and (8) design programs that extend beyond the City's immediate jurisdiction, which may require strategic partnering with homeowners, the County, municipal authorities, and businesses. Our study provides guidance on how to meet these recommendations.

The authors understand that organizations routinely set emissions reduction goals to support sustainability initiatives. Our results suggest that is will be difficult and expensive to achieve stated reductions. Therefore, we recommend establishing reduction targets that are supported by quantifiable analyses. For action items not readily quantifiable, such as behavioral items, we recommend reasonable assumptions be made and published for quantification and performance measurement. We also recommend the City, PCI, and its partners explore opportunities to leverage potential long-term savings by strategically partnering with homeowners, the County, municipal authorities, and businesses.

2. Introduction

Across the world in research centers and universities, boardrooms and convention centers, people are working towards solutions to the planet's rising temperatures, sea levels, and overall change in climate. It has been widely accepted by the scientific community that greenhouse gas emissions (GHG) caused by human activity contribute to the environmental impacts. Sufficient action must be taken now to reduce these emissions, and local citywide plans are a uniquely situated place to start. Currently, half of the world's population and one-third of the United States population reside in urban areas. Capitalizing on these densely populated areas provides a significant opportunity to take action. Although cities tend to have lower carbon emissions per capita than the national average, their densities allow for small impacts to go further. Single policy actions can govern over larger areas, populations, businesses and industries, which then can add up to a large reduction in carbon emissions. Benefits such as large centralized utilities, common ideals and behaviors, shared amenities and more will help progress this process. Without effective policies, legislation, and widespread cooperation, carbon emissions will likely not see the reduction needed to diminish the threat of global climate change.

Many cities share common elements like public transit, dense housing, walk-ability, large scale infrastructure, vehicle congestion, airports, and so forth. These similarities allow them to collaborate and share experiences with action items. There is a need for a sizeable database of proposed and enacted climate action plan measures for this collaboration amongst cities. For example, if Pittsburgh and Detroit are of similar climates, they may be able to successfully achieve similar results with building energy retrofits or green roofs. Las Vegas and Phoenix may share data on the effectiveness of solar water heaters, and so on. This will make it easier for cities that need a push to get started and motivate policy makers to take actions that have already proven to be effective in reducing emissions.

Cities are also a particularly great place to reduce carbon emissions because of the closely connected communities that tend to form within them. It is common for cities to be sectioned off into districts where people of the same background, ethnicity, socioeconomic status, and age might live. There are different strategies that will work best for attracting each group to participate and feel motivated about how they can participate in GHG reductions. Appealing to various population sectors within cities can help everyone get involved due to their sense of community pride.

In addition to reducing greenhouse gas emissions, there are many benefits cities will see from taking action. There will be financial savings from reduced utility and fuel costs from building retrofits and vehicle fleet improvements that will benefit the local government itself, community households, and businesses. Economic development is also likely from new local jobs resulting from investing in local products and services, thus keeping money circulating within the local economy. Reducing greenhouse gases will also reduce general pollution in the area, which will result in improved air quality and a generally healthier community.

The City of Pittsburgh, the Pittsburgh Climate Initiative (PCI), and their partners have taken a significant first step towards making Pittsburgh a leader in sustainable cities. As members of this community, we are grateful and elated to have local visionary leaders willing to commit resources to enhancing our community's sustainability.

We extend a heartfelt thanks to the City, PCI, and everyone involved in developing Pittsburgh's first Greenhouse Gas Inventory and Climate Action Plan. A special thanks to Lindsay Baxter, the Sustainability Coordinator for the City, and Aurora Sharrard, Research Manager for the Green Building Alliance, for their guidance and giving us the opportunity to participate.

3. Background

3.1. Tools to Assist Cities

Local governments across the nation are taking initiative to make their cities more sustainable. As city government officials often do not have the means or capabilities to complete greenhouse gas (GHG) inventories, determine the best solutions for their city, and implement those solutions, cities have been looking toward available resources to assist with these tasks. A few of these resources include the Environmental Protection Agency (EPA), Clean Air-Cool Planet (CA-CP) and ICLEI's 'Clean Air Climate Protection' tool. These agencies and programs provide tools and resources for climate action initiatives of local governments.

3.2. Environmental Protection Agency

The EPA has extensive resources for local governments, including assistance in GHG inventories, analysis of emissions and reduction potential, and quantification of energy, environment, and economic benefits of emissions reduction.[1] The EPA provides tools such as GHG inventory analytical tools, data sources, and case studies for local governments to use in developing a climate action plan. The EPA published a document in February 2008 titled "Programs, Tools, & Resources to Assist Local Governments – Implementing Your Climate Action Plans." This provides information on funding, climate action plan implementation, and other resources available through the EPA. This document is a compilation of the multiple EPA resources, with information ranging from recycling, to carbon sequestration, to clean school buses.[2]

3.3. Clean Air Cool Planet

Another resource available to municipalities is the CA-CP Community Toolkit. This toolkit focuses on communities throughout the northeast and is used to assist the implementation of cost effective sustainable projects. The toolkit has best practices of projects focused on energy, waste, transportation, and land use. CA-CP works with ICLEI and other organizations to provide support for local government climate action.[3]

3.4. ICLEI

ICLEI is an additional resource available and is a membership association of local governments committed to climate protection and sustainable development. ICLEI has grown to involve

[1] http://www.epa.gov/climatechange/wycd/stateandlocalgov/tools_resources.html
[2] http://www.epa.gov/region09/sustainable-cities/EPA_Programs_Directory-LocalGov-v3.pdf
[3] http://www.cleanair-coolplanet.org/for_communities/

nearly 1,000 cities worldwide, more than half of which are located in the U.S. since its foundation in 1990[4].

There are five milestones for cities to undergo to create a standardized means of calculating GHG emissions and establishing reduction goals. At this point there is no requirement for cities to become carbon neutral, they are just strongly encouraged to have a CO2 mitigation plan.

Milestone 1: Conduct a baseline emissions inventory and forecast
Milestone 2: Adopt an emissions reduction target for the forecast year
Milestone 3: Develop a Local Action Plan
Milestone 4: Implement policies and measures
Milestone 5: Monitor and verify results

These milestones are aimed at being flexible so that cities of all levels of analysis, effort, and availability of data can partake in the efforts.[5]

Members of ICLEI have access to many tools and resources dedicated to aiding local governments in climate action initiatives. These resources include software, training, inventory protocols, consulting and financing options. In addition to providing guidance and other tools to local governments, ICLEI also can act as a network to discuss successful case studies, and climate initiatives that have already been initiated by local governments.

ICLEI also provides to its members the Clean Air Climate Protection (CACP) software. This software is instrumental in both developing a baseline emissions inventory and quantifying the emissions reductions associated with climate action.[6] In conjunction with this software is the Local Government Operations Protocol, which is designed to be part of the official protocol for GHG inventories of United States local governments.

Another tool available through ICLEI is the Climate and Air Pollution Planning Assistant (CAPPA). CAPPA is a decision support tool designed to help local governments develop tailored, effective climate action plans based on the experiences of the ICLEI network[5].

For the inventory verification, the ICLEI software tested against spreadsheet estimates of emissions calculated using reported fuel use and emissions factors . The 2003 Pittsburgh inventory also utilized ICLEI software to calculate emissions. The 2003 inventory however did not provide a repeatable framework for performing emissions inventories in the future. Also, some of the values including emission factors from the 2003 inventory were not cited well enough to know how they were generated.

ICLEI software can only determine emissions as accurately as the inputs put into the software. Since the 2009 inventory verification was going to carefully note all assumptions and document

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[4] ICLEI. Local Governments for Sustainability. About ICLEI. http://www.icleiusa.org/about-iclei
[5] www.iclei.org
[6] http://www.icleiusa.org/programs/tools

how all inputs were determined, it only made sense to show the final calculation of emissions since the software would only accomplish the same task. For these reasons, it was decided that the 2009 inventory verification would utilize the ICLEI software only for a comparative basis and not relied upon for the final emission calculations.

The software breaks emissions for a city into four sectors including commercial, industrial, residential, and transportation. The software requires inputs of how much energy was used by each of the sectors such as quantities of electricity and natural gas for the residential sector, or the amount of gasoline and diesel consumed in the transportation sector. Other inputs to the software include the emissions factors for each type of fuel that might be unique to any given city. Once these values have been inputted, the software will calculate the emissions.
The ICLEI software falls short of quantifying emissions for a city that has not determined the inputs needed for the software. For instance, without knowing the amount of electricity or natural gas consumed by the different sectors, the ICLEI software will not be able to determine the emissions. There is no built in estimate for a city based on location or region. However, if a city is willing to seek accurate data on energy usage, ICLEI provides an easy way to determine the emissions.

3.5. ICLEI 2008 Membership Survey

The first annual ICLEI membership survey was conducted in the Fall of 2008 in order to identify and address ICLEI members' needs[7]. The study found that more than 92% of the participants had a desire for common standards for greenhouse gas accounting. ICLEI responds to this finding by noting that in 2008, they released Part 1 of a new national standard called the Local Government Operations Protocol (LGOP). Part 2 of the standard is set for release in 2009. ICLEI also notes that Project 2 Degrees, which is a new version of the current web-based software is set for release in 2009.

The survey also identified that 60% of the survey respondents claimed financing to be the greatest barrier to accomplishing emissions reductions. According to ICLEI, there is now more information pertaining to identifying sources of funding for climate change initiatives located on their website.

The survey also concluded that 66% of participants expressed the need for more resources on the ICLEI USA website such as successful case studies, guidebooks and sample polices. ICLEI now includes the Member Center, which is a section of the ICLEI USA website stocked with resources, forums and peer networking.

A majority of survey participants also stated that reducing emissions from the transportation sector is a high priority. The participants expressed the need for support in strategies to reduce vehicle miles traveled (VMT). ICLEI's Transportation and Climate Change Project brought together more than 20 communities and regional organizations to develop strategies for decreasing greenhouse gas emissions by reducing VMT and increasing passenger and freight rail. A portion of the ICLEI website now offers factsheets, case studies and implementation

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[7] ICLEI. Local Governments for Sustainability. 2008 Membership Survey Results. http://www.icleiusa.org/about-iclei/members/2008-iclei-usa-membership-survey

matrices allowing other regions to replicate this work. EPA also funded the Northeast Clean School Bus Initiative, which is committed to reduce school bus diesel exhaust. Using the Clean School Bus Section of the ICLEI website, other local governments can replicate this success by viewing case studies and other toolkits on diesel retrofits, biodiesel switches, and anti-idling campaigns.

One of the most reoccurring themes from the survey was that members seek more easy ways to connect with other local governments working on climate action and sustainability initiatives and to share best practices. The new Member Center section of the ICLEI USA website will hopefully help to address this issue.
Another goal of the Member Survey was to address in addition to needs, member priorities. The survey found that 95% of respondents cited cost savings as their top priority. ICLEI's Revolving Energy Fund Guide, Energy Star resources page and Energy Office Initiative provide members with strategies and best practices that have shown success in other communities.

Overall, the Member Survey was conducted to address member needs and top priorities when addressing climate change initiatives. As seen from the survey, local governments undertaking climate change initiatives are seeking guidance and direction since greenhouse gas accounting remains such an immature field. ICLEI is a good resource for obtaining guidance, training, and viewing success stories in other cities, but the actual work of obtaining data on particular cities concerning fossil fuel usage is still required of anyone undertaking a climate action plan for their community.

3.6. Issues of Cities versus Metropolitan Areas

Cities' metabolic processes are complicated. As concentrated centers of commerce, entertainment, recreation, and culture; materials and energy constantly flow across city boundaries. Allocating these fluxes to cities can be difficult.

In the context of climate action plans, activities related to transportation – passenger and freight - are most challenging to allocate. This is true for all transportation modes - air, water, and road – as well as both public and private transportation.

There are currently no standard practices for allocating regional activities to cities. However, such allocation may in fact be necessary to meet climate action plan objectives. For example, as end destinations for most regional commuters, do cities not play an important role in dictating emissions from road travel? London, England, in fact, now charges a toll for vehicles entering the city. If emissions cannot be allocated city-related travel, such policies cannot be adequately analyzed.

This inventory attempts to allocate activities appropriately where possible along with documenting allocation methods and assumptions.

3.7. Information Needed to Help Cities Reduce Emissions and Meet Goals

The main goal of creating a GHG inventory and drafting a climate action plan is to reduce the current emissions associated with various sectors in a municipality. Climate action plans include a goal for emissions reduction as a percent reduction by a specified year from the baseline inventory. It is necessary for local governments to determine a goal that is both attainable and effective. In order to determine an emissions percent reduction goal, local governments need to know many parameters that influence the effectiveness of emissions reduction strategies, some of which are listed below.

- Emissions reduction potential of strategy
- Cost of strategy, capital and/or annual costs
- Who is going to bear the cost
- Reduction strategies already in place
- Projected city growth or development, and associated emissions increase
- Projected participation of behavioral strategies
- City specific strategy effectiveness
- National and state programs for financing and assistance
- Climate Action Plans for the state or county level
- Case studies of other cities

These parameters are important to consider because the reduction goal may not be realistic if they are not incorporated into the determination of the goal. Emissions reductions associated with behavioral strategies are difficult to measure, but should be estimated if possible. It is also very important to consider reduction strategies that are specific to the municipality, as a strategy that worked in one city may not work in another. The cost of each strategy must be evaluated in multiple dimensions because an annualized cost, the cost per ton of GHG emissions reduced, or cost per capita may inhibit a strategy from being implemented. The projected growth of the city is also essential because emissions will grow with any development, which will directly affect the reduction goal. Knowing what national and state programs and agencies already in place for financing and assistance is beneficial because there may be opportunities to lower the cost and increase the effectiveness of certain strategies. It is also important to be aware of climate action plans that the surrounding county or state has already developed or is in the process of developing as collaboration could be beneficial. Finally, local governments should research the reduction strategies of other cities in the geographical region and across the nation to find both best practices and unsuccessful approaches.

4. 2009 Inventory Verification

4.1. Summary

In 2003, a Greenhouse Gas (GHG) inventory (referred to as the '2003 inventory' throughout this report) was conducted for the city of Pittsburgh[8]. The purpose of the 2003 inventory was to obtain an estimate of the annual GHG emissions for the city. In 2009, an inventory verification (referred to as the '2009 inventory verification throughout this report') was conducted as part of this project, which included developing a separate comparative inventory estimated from public data sources.

The 2009 verification provides a transparent comparison for the 2003 inventory, which was estimated from proprietary fuel use data. Aside from a comparative reference, the 2009 inventory verification also provides a repeatable framework for future GHG inventory analysis.

The 2009 inventory verification aimed to provide sources behind the inventory that could be reused and updated by anyone wishing to perform an inventory in the future. The 2003 inventory utilized actual consumption data for the sectors, which was provided by utilities. Since this information is proprietary, public data sources were utilized for the 2009 inventory verification. A comparison of the sources used for the two inventories to determine fuel consumption by the different sectors is shown in Table 4.1.

The 2009 verification benchmark years were limited to those applicable to the data sets used for verification. Benchmark years for the 2009 verification range from 2001 to 2005, resulting in minor temporal variations between the 2009 verification and the 2003 inventory.

Table 4.1. Comparison of Inventory Sources/Methods

Sector	Measure	2003 Inventory Source/Method	2009 Inventory Verification Source/Method
Residential	Electricity	Duquesne Light	Residential Energy Consumption Survey
	Natural Gas	Dominion Peoples Gas*	
Commercial	Electricity	Duquesne Light	(1) Energy Use by Floor Space Estimate, (2) Economic Input-Output Method
	Natural Gas	Dominion Peoples Gas	
Industrial	Electricity	Duquesne Light	(1) US GHG Inventory, (2) Bureau of Economic Analysis using GDP
	Natural Gas	Dominion Peoples Gas	
Transportation	Vehicle Miles Traveled	Southwest PA Commission	(1) Transportation Energy and Carbon Footprints, (2) National Household Travel Survey

*Three companies supply Pittsburgh with natural gas: Dominion Peoples Gas, Equitable Gas, and Columbia Gas. Only Dominion Peoples provided exact usage for Pittsburgh for the 2003 inventory. The remaining totals across each sector were estimated using Allegheny County consumption figures provided by the Pennsylvania Public Utility Commission (PUC).

[8] Pittsburgh Climate Initiative. 2006. http://www.pittsburghclimate.org/

4.2. Comparison of 2003 Inventory and 2009 Inventory Verification

Table 4.2 shows the comparison of the 2003 inventory estimate with the 2009 inventory verification estimate for Pittsburgh. It should be noted that the 2003 inventory only reported GHG emissions from The City of Pittsburgh, while the 2009 inventory verification extends the boundary to include Allegheny County and the Pittsburgh Metropolitan Statistical Area (MSA) due to the reasons mentioned above.

Two estimates are provided for some sectoral 2009 inventory verifications. The separate estimates result from different methodological approaches, as discussed in Sections 4.4 – 4.7.

Table 4.2. Comparison of Inventory Estimates

The 2009 verification "Estimate 1" represents the estimate reported for comparative purposes. "Estimate 2" is for reference only.

Community Sector	2003 Inventory (million tons eCO2)	2009 Verification (City) Estimate 1 (million tons eCO2)	2009 Verification (City) Estimate 2 (million tons eCO2)	2009 Verification (Allegheny County) (million tons eCO2)	2009 Verification (Pittsburgh MSA) (million tons eCO2)
Residential	1.22	1.35	NA	5.23	10.81
Transportation	1.31	1.25	1.17	5.21	10.09
Commercial	3.73	2.83	NA	3.46	6.54
Industrial	0.43	1.38	1.82	5.98	10.58
Sub-total*	**6.60**	**6.81**	**NA**	**19.88**	**38.02**
Pittsburgh Intern. Airport	NA	0.74	NA	NA	NA
Port of Pittsburgh	NA	0.36	NA	NA	NA
PAT	NA	0.12	NA		
Total	**6.60**	**8.46**	**NA**	**19.88**	**38.02**

*Numbers may not add due to rounding.

The 2003 greenhouse gas inventory is within 3% of the 2009 inventory verification, excluding the airport, the Port Authority, and the Port of Pittsburgh. However, the 2003 commercial sector estimate is 30% higher than the 2009 verification, and the 2003 industrial sector estimate is 70% lower then the 2009 verification.

Such differences are potentially significant depending on the CAP goals and how performance is measured. Measured reductions in the future may be artifacts of an inaccurate inventory. For example, if the target commercial sector reduction is 20% and the inventory is 20% high, then an accurate inventory may be perceived as having met the target, when no actual emissions reductions occurred.

GHG emissions are estimated as the product of fuel use estimates and an emissions factor. Thus inventory discrepancies can arise from either differences in fuel use, an emissions factor, or both.

The emissions factors and fuel use data used in the 2003 inventory and 2009 inventory verification are summarized in Table 4.3. The purpose of this table is to highlight the major differences in the inputs to both inventories, which are shaded in Table 4.3.

The 2003 inventory used an emissions factor for electricity that is high relative to domestic values published by the EIA.[9] Similarly, in the case of natural gas consumption in the residential sector, the 2003 inventory has reported significantly low use as compared to the 2009 inventory verification. Similar cases may be observed for other sectors as well. However, it is acknowledged that the 2009 inventory verification may have overestimated actual emissions with the industrial sector, which may account for an order of magnitude difference in the consumption figures for natural gas. The important takeaway for the 2009 inventory verification, was to document sources well so that the methods used to arrive at emissions could be repeated and verified, as well as updated in the future.

Table 4.3. Emissions Factors and Consumption Comparison
Shaded Cells Show Major Differences Between 2009 Verification And 2003 Inventory

Fuel	Consumption Units	Emissions Factors Units	Emissions Factors 2003 Inventory	Emissions Factors 2009 Verification	Residential 2003 Inventory	Residential 2009 Verification	Transportation 2003 Inventory	Transportation 2009 Verification	Commercial 2003 Inventory	Commercial 2009 Verification	Industrial 2003 Inventory	Industrial 2009 Verification
Elec	mil kWh	lb eCO2/kWh	2.29	1.7	840	1,000			3,000	2,200	280	430
Nat Gas	bil CF	lb eCO2/CF	0.12	0.12	4.1	10			3.9	6.5	1.6	17
Gasoline	mil gal	lb eCO2/gal	21.4	19.4			100	97				
Diesel	mil gal	lb eCO2/gal	24.2	22.2			18	28				
Fuel Oil	mil gal	lb eCO2/gal	-	25.7					0	0.014		
Jet Fuel	mil gal	lb eCO2/gal	-	21.1								

From the observations in Table 4.3, the need for well documented estimation methods are considered critical - both in terms of easing the validation process, as well as paving the way for future inventories. The 2003 inventory reported that the emission factors were obtained using EPA, DEP, and EIA sources and that the electricity emission factor was customized to reflect Pittsburgh. It does not however explain how this customization was done. A possible explanation could be that the ICLEI software gave the high value for electricity, but this was not clear. The 2009 inventory verification therefore derived a new emissions factor for electricity which was applied to all electricity usage throughout the inventory.

4.3. Expanding the Inventory Boundary

In addition to the emissions estimated above, the 2009 inventory verification also included an estimate for the GHG emissions associated with the Pittsburgh International Airport (PIT), the Port of Pittsburgh, and the Port Authority Bus System (PAT). These three quantities were not included in the 2003 inventory. The reason for the inclusion these modes of transportation in the 2009 inventory verification, was that the boundary was extended to cover Allegheny County which would certainly include PIT as well as the Port of Pittsburgh. The PAT is a big part of

[9] EIA-Voluntary Reporting of Greenhouse Gases Program - Emission Factors and Global Warming. Available at: http://www.eia.doe.gov/oiaf/1605/emission_factors.html [Accessed July 8, 2009].

transportation throughout the City of Pittsburgh on a daily basis and therefore was included as well. The emissions associated with these forms of transportation are described in detail later in the report.

4.4. Residential Sector

The 2003 inventory provides an estimate of the annual emissions from the residential sector. However, the methodology for determining residential emissions is not clearly documented in the 2003 inventory. The annual carbon emissions attributable to the residential sector were estimated again in order to verify the emissions and provide clearly documented calculations and data sources. The method is detailed below.

The annual greenhouse gas emissions from residential buildings are determined by collecting data on annual energy consumption by type and then multiplying the type of energy by an appropriate emissions factor. The residential energy consumption data is from the Residential Energy Consumption Survey (RECS) for 2001[10]. RECS is a nationwide survey of U.S. households that collects and summarizes energy consumption by source (e.g. fuel type) and end-use. The quantity and type of fuel consumed per household is used to estimate the residential emissions. The survey data is divided into the following census regions within the U.S.:

- Northeast
- South
- West
- Midwest

The Northeast Census Region is subdivided into the Middle Atlantic and New England Census Regions. The Middle Atlantic region is most representative of Pittsburgh because it covers the state of Pennsylvania. The household energy consumption for the Middle Atlantic Region is shown in Table 4.4.

Table 4.4. 2001 U.S. Household Census Data for Middle Atlantic Region[1]

Annual Consumption Per Household	Middle Atlantic	Northeast	Midwest	South	West
Electricity (kWh)	7,799	7,624	9,727	14,240	8,287
Natural Gas (MMBTU)	77.4	78.3	94.7	60.4	55.0

Table 4.5 summarizes the proportion of households that utilize various types of fuel. Fuel oil, kerosene, liquefied propane gas and wood are energy sources used primarily in rural areas. For the purpose of this analysis, which focuses primarily on urban and suburban areas, these energy sources were replaced with natural gas. The RECS data was modified so that all households use only electricity and natural gas. The last four rows in Table 4.5 were ignored and the percent of households using natural gas was increased to 100.

[10] 2001 Residential Energy Consumption Survey: Household Energy Consumption and Expenditure Tables, Energy Information Administration, Table CE1-9c. http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls.html

Table 4.5. Energy Consumption per Household by Census Region[1]

	Households (millions)	Percent of Households Using
Total	**14.8**	-
Electricity	14.8	100%
Natural Gas	10.3	70%
Fuel Oil	3.9	26%
Kerosene	0.4	3%
LPG	1	7%
Wood	1.3	9%

City and MSA Emissions Estimation

U.S. census data shows that Allegheny County and the Pittsburgh metropolitan area have a population of 1.2 and 2.7 million, respectively[11]. The number of households per boundary region is scaled by population. The results are shown in Table 4.6.

Table 4.6. Population and Households by Boundary Region

	Population	Households
City of Pittsburgh	300,000	132,000
Allegheny County	1,300,000	430,000
Pittsburgh MSA	2,700,000	1050,000

By scaling the household data from a region as large as the Middle Atlantic down to the city of Pittsburgh, multiple assumptions regarding household characteristics are made which can affect the precision of the results. For example, the square footage of houses within the city is significantly different from suburb residences. Additionally, more affluent households which are typically in the suburbs have different levels of energy consumption.

Scaling the data from Table 4.4 and Table 4.5 to Pittsburgh, which is estimated to have 132,000 households in the city and therefore 1,050,000 households within the metropolitan area, the total residential emissions can be determined.

Table 4.7 summarizes the estimated annual residential emissions for the city and metropolitan area of Pittsburgh. As seen from Table 4.7, the emissions from the metropolitan area are a factor of eight higher than the city of Pittsburgh. This factor is in proportion to the increase in households in the metropolitan area. Both the city and metropolitan area emissions can be scaled to estimate the Allegheny County emissions. Given that the county population is roughly four times the size of the city population, the county emissions would be a factor of four higher than the city emissions.

[11] 2006 US Census Bureau

Table 4.7. Total Residential Emissions

	City		Metropolitan Area	
Energy Source	Consumption (million)	Emissions (million tons eCO2)	Consumption (million)	Emissions (million tons eCO2)
Electricity (kWh)	1,030	0.79	8,230	6.36
Natural Gas (MMBTU)	10.2	0.56	81.6	4.45
	Total	1.35	**Total**	10.81

Energy Consumption End Use

Next, the residential energy consumption was broken down by end-use. The end-use of energy consumed in the residential sector is also shown in the RECS data. Again, for Pittsburgh the Middle Atlantic Census Region was chosen as the most representative. Considering the end use of energy in the residential sector allows for more accurate valuation of carbon mitigation strategies which might focus on a single end use (e.g., lighting). Table 4.8 lists the different energy uses and the corresponding percentage of energy use.

Table 4.8. Energy Consumption per Household by Use[1]

	Percent of Households	**Energy (million BTU/HH)**	**Percent of Total Energy**
Space Heating	99%	60.1	57%
Air conditioning	75%	3.4	3%
Water Heating	100%	17.4	16%
Refrigerators	100%	4.3	4%
Other Apps & Lighting	100%	20.3	19%

In Table 4.8, the Percent of Households column refers to homes that have the specified end-use. For example, only ¾ of households in the Middle Atlantic Census Region have air conditioning. Therefore, a mitigation option affected by residential air conditioning systems will only apply to 75 percent of households.

4.5. Transportation Sector

The 2003 inventory for the city of Pittsburgh reported approximately 1961 million vehicle miles traveled annually, with total emissions of 1.31 million tons of eCO2 attributable to the transportation sector. To verify these numbers, the 2009 inventory verification estimates vehicle miles traveled, fuel consumed, and emissions contributed by the transportation sector within the city. Three of the methods used to approximate these values are described in the following sections.

Method 1: Metropolitan Statistical Area (MSA) level VMT data
The paper titled "The Transportation Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas"[12], published by a group at Georgia Institute of Technology, reports vehicle miles of travel (VMT) in different Metropolitan Statistical Areas (MSA) for the year 2005. This VMT data is segregated by type of vehicle (auto, single-unit trucks and combination trucks). The data sources for these values include the Highway Statistics Report and the Highway Performance Monitoring System, both published by the Federal Highway Administration (FHWA) for Urbanized Areas in the US every year. The paper uses the raw HPMS data of sampled vehicle counts that was available, to obtain estimates of VMT for the 100 top Metropolitan Statistical Areas (which differ slightly in boundary definition, from the Urbanized Areas). The MSA level data reported in the paper is scaled down linearly by the population to estimate the VMT in Allegheny County and City of Pittsburgh. Per capita annual VMT is calculated for the MSA by dividing the total VMT with the population of the MSA, as reported by the U.S. Census Bureau [13]. The VMT per capita is assumed to be the same at the county and city level also. This value is multiplied by the total population of Allegheny County to obtain VMT estimates for the county. Similarly, to estimate VMT for the City of Pittsburgh, the VMT per capita is multiplied by the total population of the city. To calculate the fuel consumption, all autos were assumed to run on gasoline while all trucks were assumed to run on diesel. Using fuel efficiencies of autos (22.9 mpg), single-unit trucks (8.8 mpg) and combination trucks (5.9 mpg), as reported in the Transportation Energy Data Book[14], the total annual fuel consumption is calculated at the city, county and MSA level, by multiplying VMT by the fuel efficiencies for each type of vehicle. Emissions due to fuel consumption are calculated by applying emissions factors for gasoline (19.4 eCO2/gallon) and diesel (22.2 eCO2/gallon) as given by the EPA report, "Unit Conversions, Emission Factors, and Other Reference Data"[15]. The total annual emissions due to the transportation sector are calculated as the product of the annual fuel consumption and the emissions factors for each fuel type. The total emissions thus estimated for the city are found to match closely with the values reported in the 2003 inventory.

Method 2: National Household Travel Survey – allocation by households
The Federal Highway Administration (FHWA) publishes the National Household Travel Survey[16] that reports values of daily vehicle miles of travel (DVMT) per household (for private vehicles), trip purpose, and the total number of households. This data is reported at the county level with segregation by Census tract IDs as well as Transportation Analysis Zones (TAZ). VMT annually by private vehicles in Allegheny County is calculated by multiplying the DVMT per household reported for the county, by the number of households within the county and by the number of days in a year (365). The Pittsburgh MSA consists of Allegheny, Armstrong, Beaver, Butler, Fayette, Washington and Westmoreland counties and the annual VMT for the MSA is estimated to be the sum of the vehicles miles traveled in the constituent counties. Assuming that 8% of total vehicle miles traveled are contributed by trucks (as given in the Georgia Tech

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[12] The Transportation Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas, *Southworth Frank, Sonnenberg Anthon, Brown Marilyn A.*
[13] US Census Bureau – Dataset: 2005 American Community Survey
[14] Tables 4.1, 5.1, 5.2 - Transportation Energy Databook 2007
[15] http://www.epa.gov/appdstar/pdf/brochure.pdf
[16] http://nhts.ornl.gov/

working paper) the total annual VMT for the MSA and Allegheny County is calculated as the sum of travel by private vehicles and trucks. An average value of the number of annual VMT per household based on Allegheny County is multiplied by the estimated number of households in the city, to obtained annual VMT for the City of Pittsburgh. Further, using fuel efficiencies and emission factors used in the previous method, the total emissions are calculated for the Pittsburgh MSA, Allegheny County as well as for the City of Pittsburgh. The annual VMT thus estimated is 10% higher than the values reported in the 2003 inventory, while the emissions are 10% lower, due to the difference in emissions factors used. It was also observed that although the trucks contributed to 8% of the annual VMT, they are responsible for nearly 24% of the total emissions in the area. This is due to the fact that: a) trucks have lower fuel efficiencies as compared to passenger vehicles; and b) their use of diesel fuel that has higher associated emissions per unit volume than gasoline.

Method 3: National Household Travel Survey – allocation by GIS Data

As an alternate method of estimation of emissions at the city level, Census Tract IDs within the City of Pittsburgh are obtained from GIS data. VMT data specific to these census tracts are extracted from the NHTS data used above and their sum represents the vehicle miles traveled by households existing within the city limits. This VMT value of approximately 1,450 million for private vehicles in 2001 is found to be much lower than any of the previous estimates. Assuming that 8% of the total VMT is due to truck travel, the total annual VMT for the city is estimated to be 1,525 million. Using the same emission factors applied in the previous methods, the emissions for the households within the city, due to transportation, is found to be approximately 813,000 tons eCO2. The VMT estimated is about 22% lower than the value reported in the 2003 inventory while the emissions are about 38% lower.

Since the NHTS data indicates travel per household basis, the VMT estimate for the city includes only distance traveled by persons in households within the city limits and does not account for travel into the city from neighboring suburban areas. Hence the low VMT value obtained in the previous estimate can be justified. However, an allocation problem exists, which focuses on whether or not to include emissions due to travel within the city, by people living outside the city municipal limits. On the other hand, all the vehicle miles traveled by households within the city, may not necessarily be within the city and segregation by trip purpose may be of further interest.

The greenhouse gas emissions associated with the transportation sector for various cities in the US are estimated using data on vehicle miles of travel publicly available. This is similar to method 1 of estimating transportation emissions for the City of Pittsburgh. The Federal Highway Administration (FHWA) reports the daily vehicle miles traveled (DVMT) through the Highway Statistics Report for different years[17]. For the year 2005, the table HM71 data was used, which contained population figures, road lengths (in miles) and DVMT estimates for different Federal-Aid Urbanized Areas within the US, as defined by the Bureau of Census. The miles and vehicle miles traveled data is segregated by type of road – namely, Interstate, Other Freeways and Expressways, Other Principal and Arterial, Minor Arterial, Collector and Local.

[17] Federal *Highway* Administration, *Highway Statistics 2005, Table HM71 – Urbanized Area 2005 – Miles and Daily Vehicle-Miles of Travel, http://www.fhwa.dot.gov/policy/ohim/hs05/htm/hm71.htm*

The DVMT was converted to annual vehicle miles traveled totally for each urbanized area. This was allocated by population (as shown in method 1 previously) within city limits as reported by the US Census Bureau, to obtain VMT estimates for the different cities. Assuming that 8% of total vehicle miles traveled is contributed by trucks (single-unit and combination)[18]; the total vehicle miles traveled within city limits was calculated.

Based on annual VMT, using fuel efficiencies and emission factors for each type of vehicle reported in the Transportation Energy Data Book[19], fuel consumption data and corresponding eCO2 emissions were calculated. The fuel efficiencies and emission factors for different types of vehicles, along with percentage of total VMT used for calculation purposes are summarized in Table 5.2 later in the report.

A summary of the emissions associated with the transportation sector are illustrated in Table 4.9.

Table 4.9. Transportation Emissions Summary

Area	**Estimate 1**		**Estimate 2**		**Estimate 3**		**2003 inventory**	
	VMT	**eCO2 emissions**	**VMT**	**eCO2 emissions**	**VMT**	**eCO2 emissions**	**VMT**	**eCO2 emissions**
	(million)	(million tons)	(million)	(million tons)	(million)	(million tons)	(million)	(million tons)
Pittsburgh	2412	1.25	2190	1.17	1525	0.81	1961	1.31
Allegheny county	10072	5.21	8023	4.28	8021	4.28		
Pittsburgh MSA	19504	10.09	16769	8.94	16769	8.94		

4.6. Commercial Sector

The emissions from commercial buildings are estimated using two methods: (1) energy use per floor space estimates and (2) economic input-output methods. Each of these methods and associated data sources are briefly discussed below.

Commercial Buildings Energy Consumption Survey Summary

Commercial Buildings Energy Consumption Survey (CBECS) [20] is a national commercial energy use survey conducted once every four years. CBECS surveys building owners for building stock characteristics, energy use mechanisms, and energy consumption. CBECS defines "commercial" buildings to include all activities except residential, agricultural, and industrial.

[18] The Transportation Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas, *Southworth Frank, Sonnenberg Anthon, Brown Marilyn A*

[19] Transportation Energy Databook 2007

[20] Energy Information Administration (2005) Commercial Buildings Energy Consumption and Expenditures, 2003. Commercial Buildings Energy Consumption Survey, U.S. Department of Energy. Accessed January 2009 at http://www.eia.doe.gov/emeu/cbecs/.

CBECS publishes energy use by the following fuel types and end uses:

- Heating (Electricity, Natural Gas, Fuel Oil, District Heat)
- Cooling (Electricity, Natural Gas, Fuel Oil, District Heat)
- Ventilation (Electricity)
- Water heating (Electricity, Natural Gas, Fuel Oil, District Heat)
- Lighting (Electricity)
- Cooking (Electricity, Natural Gas, Fuel Oil, District Heat)
- Refrigeration (Electricity)
- Office equipment (Electricity)
- Computer (Electricity)
- Miscellaneous (Electricity, Natural Gas, Fuel Oil, District Heat)

The major limitations in using CBECS for inventorying energy and GHG emissions at the city level are statistical significance and geographic resolution. The 2003 survey contained just over 5,200 buildings. Results are published by four Census Regions, nice Census Divisions, and five climate zones.

Floor Space and Energy Use Emissions Estimates
Energy use is estimated as the product of energy use per unit of floor space (BTU/sf) and total floor space (sf). Energy use per floor space estimates is taken from the Commercial Buildings Energy Consumption Survey (CBECS).

Three methods are used to estimate total commercial floor space: (1) geographic information system data, estimates provided by the commercial real estate firm CBRE; and (3) economic output (GDP) per floor space published by EIA.

Geographic Information System (GIS) Data
Geographic information system (GIS) files of building footprints, zoning, and neighborhoods are used to estimate total building footprints by zoning type and neighborhood.[21] This data is available only for the City of Pittsburgh. For each building type and location, an average number of floors is assumed. The assumed average number of floors is shown in Table 10.1 in the Appendix. The average number of floors multiplied by the total building footprint gives an estimate of the commercial floor space.

CBRE Estimates
CB Richard Ellis (CBRE), a commercial real estate services firm, provided retail floor space estimates for Beaver, Butler, Allegheny, Washington, & Westmoreland counties and office space estimates for Allegheny County.[22] While CBRE inventories most buildings, they do not track smaller buildings. CBRE tracks data for retail buildings larger than 5,000 square feet and office buildings larger than 10,000 square feet. In addition, CBRE inventories do not represent all uses.

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[21] Geographic information systems (GIS) data was provided to Carnegie Mellon University by the City of Pittsburgh on CD.
[22] Personal communication with CBRE.

Therefore, the CBRE estimates had to be scaled to represent all buildings and all uses. In addition, the geographic delineation represented in the CBRE estimates in not consistent with our inventory goals.

Three types of scaling were completed for the CBRE commercial floor space estimates: (1) floor space for smaller buildings not tracked by CBRE are estimated using CBECS building stock distributions for the Mid-Atlantic region, (2) other commercial building uses not reported by CBRE are also estimated using the CBECS distributions, and (3) regional estimates are scaled by population. Table 10.2 summarizes the CBRE estimates in the Appendix.

GDP Floor Space Estimate
The physical capital associated with a given economic activity should be moderately consistent across the organizations engaged in the activity. As a result, the floor space required to produce a given output should be moderately consistent across companies engaged in similar activities.

EIA publishes a "crosswalk" that roughly corresponds the economic sectors to the principal building activity reported in survey responses.[23] Economic sectors are represented by 3-digit North American Industry Classification System (NAICS) codes.

Using the EIA crosswalk, total economic output,[24] and total commercial floor space, the required floor space per output of gross domestic product (GDP) is estimated for all industries based upon total national floor space and output. GDP estimates not reported at 3-digit sector resolution are estimated by allocating GDP by total sales.[25]

The results are then applied to the Pittsburgh MSA. Regional economic output[26] data not reported for proprietary reasons is approximated by allocating output by employment.[27] Results are summarized in Table 10.4.

Floor Space Estimates Summary
The commercial floor space estimates and associated emissions estimates are summarized in Table 4.10. Floor space estimates in bold font are recommended based upon analyses to date and are used in subsequent calculations.

EIO-LCA Emissions Estimate
Economic input-output life cycle assessment (EIO-LCA) techniques leverage economic supply chain relationships to estimate the full environmental impact of a product or process from raw materials extraction ("cradle") to consumer purchase ("gate"). EIO models were originally formalized by Leontief and represented a linear model of all inter-industry or inter-commodity transactions in the national economy.[28,29]

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23 http://www.eia.doe.gov/emeu/cbecs/PBAvsNAICS.xls
24 http://www.bea.gov/industry/gdpbyind_data.htm
25 http://www.census.gov/econ/census02/
26 http://www.bea.gov/regional/index.htm
27 http://www.census.gov/epcd/cbp/index.html
28 Leontief, WW (1986) " Input-Output Economics." Oxford University Press. New York.

Carnegie Mellon University's (CMU) Green Design Institute developed the method in the US. The entire EIO-LCA model is currently available for free on the web at www.eiolca.net[30].

Table 4.10. Commercial Floor Space and Emissions Estimates

		City of Pittsburgh	**Allegheny Co**	**MSA**
		Floor Space (mil sq ft)		
Method	Allocation Method(s)			
GIS	No. Floors (Assumed)	**188**	NA	NA
CBRE	Population, CBECS	NA	**229**	**435**
GDP, Total Floor Space	CBECS Crosswalk, County Business Data	NA	NA	410
Estimates in bold recommended for fuel consumption calculation		*188*	*229*	*435*
		Fuel Consumption (Based upon above floor space)		
Fuel	Unit Use			
Electricity Use (MWh)	11.64 kWh/sq ft	2,190,000	2,670,000	5,060,000
Natural Gas Use (MMBTU)	35,409 BTU/sq ft	6,660,000	8,110,000	15,400,000
Fuel Oil Use (MMBTU)	10,663 BTU/sq ft	2,000,000	2,440,000	4,640,000
		Emissions (tons eCO2)		
Fuel	Emissions Factor			
Electricity Use	1.7 lbs eCO2/kWh	1,860,000	2,270,000	4,300,000
Natural Gas	120 lbs eCO2/MMBTU	400,000	490,000	920,000
Fuel Oil	172 lbs eCO2/MMBTU	170,000	210,000	400,000
	Total	2,430,000	2,970,000	5,620,000

As an additional point of reference, GHG emissions for the Pittsburgh MSA from electricity consumption can be estimated using EIO-LCA. The 2002 benchmark EIO-LCA model uses nationally averaged inters-sector purchases as well as nationally average electricity fuel source mixes. Local deviation from the national average is expected.

2002 economic output (GDP) for the Pittsburgh MSA is documented in Table 10.3 in the Appendix.

Table 4.11 presents the EIO-LCA results. EIO-LCA results suggest that direct electricity emissions for the Pittsburgh MSA are 6.2 million tons of eCO2. This results compares favorably to the floor space estimate of 5.1 millions tons of eCO2.

[29] Bureau of Economic Analysis (2003) Capital Flow Matrix from the 1997 Benchmark Input-Output Accounts, BEA.
[30] EIO-LCA web site, http://www.eiolca.net, accessed Feb. 28, 2008

Table 4.11. Pittsburgh MSA EIO-LCA Emissions Estimate

	GDP	Direct Electricity Emissions	
Sector	**Output (M$)**	**lbs eCO2 per $**	**tons eCO2**
Transportation	2,975	0.08	125,000
Wholesale, Retail, & Warehousing	11,428	0.26	1,470,000
Info, Finance, Insurance, Real Estate	10,866	0.08	432,000
Services	10,487	0.07	350,000
Education	15,659	0.30	2,390,000
Healthcare & Social Assistance	7,800	0.13	501,000
Entertainment	2,796	0.37	518,000
Other Services	2,280	0.17	188,000
Government & Other Utilities	2,475	0.16	195,000
		Total	6,170,000

Commercial Emissions Estimates Summary

Table 4.12 summarizes 2009 inventory verification emissions estimate for the commercial sector.

Table 4.12. Summary of Emissions Estimates (tons eCO2)

	City of Pittsburgh	Allegheny Co	MSA
Commercial Emissions	2,430,000	2,970,000	5,620,000

4.7. Industrial Sector

According to the 2003 inventory, the industrial sector consists of five subsectors including: agriculture, forestry, fishing, and hunting; mining; construction; manufacturing; and utilities. The 2003 inventory accounts for the total amount of natural gas and electricity consumed by industrial uses, but it does not include the release of greenhouse gas emissions by industrial processes. The 2003 inventory used electricity and natural gas consumption data to determine the emissions associated with the industrial sector. Electricity consumption data was provided by Duquesne Light Company, the only electricity provider for the City. Natural gas consumption data was provided by Dominion Peoples Gas, which is one of three natural gas providers of the city. Total citywide consumption of natural gas for the industrial sector was then estimated based on Dominion Peoples' data. To determine the validity of the 2003 inventory report emissions, two methods were used to verify the emissions associated with the industrial sector, as described below.

2003 U.S. GHG Inventory

Because consumption data for the industrial sector in Pittsburgh is unavailable at the time, the first estimate of the City of Pittsburgh GHG emissions due to the industrial sector is based on the 2003 United States GHG Inventory. Table 4.13 shows the U.S. Inventory Report data.[31]

[31] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf

Table 4.13. 2003 U.S. Inventory Report Emissions

Industrial Emissions	**Tg eCO2**
Combustion	856
Electricity	736
Total Industrial Emissions	1,592
Total US Emissions	5,617
Industrial Emissions as % of Total US Emissions	28%

Using the data above, rough estimations of emissions in the Pittsburgh MSA, Allegheny County, and the City of Pittsburgh is determined based on population. Using a 2003 U.S. population of 290 million, it is estimated that per capita emissions for the industrial sector are 6.05 tons eCO2. This per capita emission rate is applied to the populations of the MSA, the County, and the City. Results are shown in Table 4.14.

Table 4.14. Industrial Emissions by Area

Area	**2003 Population**	**Industrial Emissions (million tons eCO2)**
U.S.	290,000,000	1,755
Pittsburgh MSA	2,300,000	13.92
Allegheny County	1,300,000	7.87
City of Pittsburgh	300,000	1.82
2003 Inventory	300,000	0.43

The 2003 inventory reported value for industrial emissions is more than 4 times lower than this population based estimate. This is possibly because populations in cities are high, while the numbers of industrial units located within a city are small. This shows that a population based analysis may be applied to the county or MSA, but it is not expected to provide accurate results for the City boundary.

Industrial Emissions by GDP

A second method used to determine the emissions in the industrial sector uses the GDP of subsectors of the industrial sector for the Pittsburgh MSA. The Bureau of Economic Analysis provides GDP data for most of the subsectors. GDP is estimated for the remaining subsectors using employment data from County Business Patterns. Table 10.4 in the Appendix shows the estimated GDP for each subsector of Industry in the Pittsburgh MSA.

Average emissions factors for each corresponding subsector are then applied to the GDP data in Table 10.3. Scope 1 (primary use), and scope 2 (electricity generation) in tons eCO2 emissions per $GDP are used. Table 4.15 shows the estimated emissions associated with various industrial subsectors in the Pittsburgh MSA.

Table 4.15. Estimated MSA Industry by GDP

Industry	GDP (Est. $Mil)	Scope 1		Scope 2		Total Emissions (million tons eCO2)
		(ton eCO2/$)	(million tons eCO2)	(ton eCO2/$)	(million tons eCO2)	
Agriculture, forestry, fishing, and hunting	102	0.0016	0.17	0.0002	0.02	0.18
Mining	1023	0.0009	0.89	0.0004	0.38	1.27
Construction	4085	0.0002	0.89	0.00003	0.11	1.01
Manufacturing	12478		5.84		2.29	8.12
		Total	**7.79**		**2.79**	**10.58**

The total MSA emissions of 10,582,000 thus estimated is then divided by the 2003 population to determine the emissions per capita, which is approximately 4.6 tons eCO2/capita. This is less than the 6.06 tons eCO2/capita estimated in the first method. MSA per capita emissions were scaled by population to estimate emissions for the County and City. Table 4.16 below shows the comparison of the two methods and how they relate to the emission estimation provided in the 2003 inventory.

Table 4.16. Comparison of Methods

Area	Million tons eCO2	
	Method 1	Method 2
	US Inventory and Population	GDP and Population
Pittsburgh MSA	13.92	10.58
Allegheny County	7.87	5.98
City of Pittsburgh	1.82	1.38
2003 inventory	0.43	0.43

Energy Consumption Verification

To further compare the results to the 2003 inventory, the electricity and natural gas consumption of the industrial sector for the City are estimated based on the above emissions estimation. Method 2 – Emissions by GDP and population is used for this estimation because it is thought to be a more accurate estimate than Method 1. To do this calculation, the estimated emissions were divided by the emissions factors for both natural gas and electricity. The natural gas emission factor of 0.12 lb eCO2/ft^3 was used along with the electricity emission factor of 1.7 lb CO_2/kWh. The emissions associated with scopes 1 and 2 correspond with natural gas consumption and electricity consumption, respectively. Table 4.17 shows the estimated natural gas and electricity consumption for the industrial sector.

Table 4.17. Energy Consumption Estimation

Scope	Emissions (million tons eCO2)	Emission Factor (lb eCO2/unit)	Unit	Estimated Consumption	Unit
Scope 1 (natural gas)	1.00	0.12	CF	17	bil CF
Scope 2 (electricity)	0.36	1.7	kWh	430	mil kWh

The consumption estimations for both natural gas and electricity are much higher than the consumption reported in the 2003 inventory. Table 4.18 shows a comparison between the estimation and the 2003 inventory. The differences can be attributed to many reasons. One is a difference in the electricity emissions factor. A second source of error could be in the estimation of the 2003 total natural gas consumption. As described above, natural gas consumption data was only provided by one of three natural gas providers of the city, which resulted in the need for estimation of total citywide consumption.

Table 4.18. Energy Consumption Comparison

Energy	2009 Verification			2003 Inventory		
	Emissions (million tons eCO2)	Emission Factor (lb eCO2/CF, lb eCO2/kWh)	Consumption (bil CF, mil kWh)	Emissions (million tons eCO2)	Emission Factor (lb eCO2/CF, lb eCO2/kWh)	Consumption (bil CF, mil kWh)
Natural Gas	1.00	0.12	17	0.09	0.12	1.6
Electricity	0.36	1.7	430	0.32	2.29	280
Total	1.36			0.42		

Industrial GHG emission estimates are complicated by the proprietary nature of the data as well as fugitive industrial process based emissions, which are not easily allocated due to the specificity of industrial processes.

Given the range in industrial emissions estimates (0.43 million tons eCO2 from the 2003 inventory to 1.82 million tons eCO2 estimated using national per capita estimates), the 2002 EIO-LCA estimate of 0.83 million tons was adopted for the 2009 inventory verification.

It should be noted that the 2002 benchmark EIO-LCA model uses nationally averaged inters-sector purchases as well as nationally average electricity fuel source mixes. Local deviation from the national average is expected.

4.8. Pittsburgh International Airport (PIT)

Airports contribute a significant amount of greenhouse gas emissions each year to their surrounding community. Sources of emissions from an airport can be divided into the following categories:[32]

[32] Port of Seattle. Seattle-Tacoma International Airport Greenhouse Gas Emissions Inventory, 2006. Prepared by Synergy Consultants, Inc, BridgeNet International. October 19, 2007.

- Aircraft emissions (including stationary, landing, take off, and cruise altitudes)
- Ground Vehicles (including all baggage handling equipment, aircraft tugs, etc)
- Infrastructure (building lighting, cooling, heating, etc)

Aircraft Emissions

According to the Air Transport Bureau, total aviation eCO2 emissions account for about 2% of global greenhouse gas emissions[33]. Allocating aircraft emissions to specific airports poses a challenging problem. For example, an aircraft departing from Pittsburgh, traveling to Miami, FL will emit emissions for the entire length of the journey and not just in Pittsburgh. Similarly, flights arriving in Pittsburgh will have contributed emissions to the total length of the flight, not just in the Pittsburgh vicinity. Different methods exist for allocating the total emissions generated from an airplane over the duration of a flight and which airport(s) the emissions from a flight should be associated with.

The Intergovernmental Panel on Climate Change (IPCC) outlines three tiers to evaluating aviation emissions.[34]

- Tier 1 – reflect total jet fuel consumed at the airport
- Tier 2 – requires a knowledge of the dispensed fuel as well as the aircraft landing and takeoff cycles, to account for cruise level energy consumption
- Tier 3 – uses a model developed by the European Environment Agency (Denmark) which requires information on the origin and destination of flights.

ICLEI has developed guidance on reporting emissions from airports.[35] According to the ICLEI standard, emissions inventories for airports for local communities should determine the total amount of fuel used by the planes on all of the flights originating at the airport. This was done for PIT by using the total volume of fuel sold at the airport in a one year period. Using this standard, a Tier 1 calculation was used for estimating the emissions from airplanes at PIT. It should also be noted the ICLEI standard states that emissions at airports resulting from infrastructure (electricity, natural gas consumption) should not be included in the final estimate for the airport emissions since infrastructure energy use should be included with the city commercial building sector estimate. The emissions from this category however will be included in the airport section of this study, since there are varying scopes of analysis for the other sectors being analyzed for the city of Pittsburgh.

PIT Estimate 1: Air Transport Association Data

According to the Air Transport Association monthly jet fuel consumption report, the United States consumed 13.5 billion gallons of jet fuel in 2007 for domestic flights.[36] The total

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[33] Air Transport Bureau. Aircraft Engine Emissions. http://www.icao.int/icao/en/env/aee.htm

[34] Intergovernmental Panel on Climate Change (IPCC). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Volume 2, Energy. Chapter 3, Mobile Combustion. Section 3.6, Civil Aviation. 2006.

[35] International Council for Local Environmental Initiatives (ICLEI), http://www.iclei.org

[36] Air Transport Association. Economics and Energy. Monthly Jet Fuel Cost and Consumption Report. http://www.airlines.org/economics/energy/MonthlyJetFuel.htm

enplanements for 2007 in the U.S. were 690 million passengers.[37] These figures amount to an average of 19.6 gallons of jet fuel per enplaned passenger in 2007, which is slightly below the national average of 21 gallons per enplaned passenger.[38] Using the total enplanements for Pittsburgh International Airport in 2007 of 4,910,957[39] and assuming 21 gallons of fuel per passenger, a total of 103 million gallons of jet fuel can be estimated for the PIT.

The US Energy Information Administration estimates that 21.095 lbs of eCO2 are produced per gallon of jet fuel.[40] Using this emission factor, a total of roughly 1.1 million tons eCO2 are estimated for the airplane emissions from PIT using this rough estimation process.

PIT Estimate 2: PIT Consumption Data

Using data provided by the PIT, there were a total of 68,206,543 gallons of jet fuel sold at PIT in 2008[41]. Using the same emission factors noted above, this equates roughly 740,000 tons of eCO2 from the jet fuel sold at PIT in 2008.

Fuel use data for onsite ground vehicles was reported to be 220,317 gallons of gasoline and 241,595 gallons of diesel fuel for 2008[10]. Using the appropriate emissions factors (used previously in the report) for each of these fuels, the emissions were calculated and can be found in the summary table below.

Natural gas usage was also supplied by PIT for 2008. PIT reported 247,745 MCF of natural gas used at the airport for 2008. The calculation for the emissions can also be found in Table 4.19. Note that the emissions factors used are the same emissions factors utilized for the different fuels throughout the inventory.

Table 4.19. PIT Emissions Estimate (2008)

Fuel Type	Units	Value	Emissions Factor	Emissions (tons eCO2)	% of Total
Gasoline	gal	220,317	19.4 lb eCO2/gal	2,137	0.29%
Diesel	gal	241,595	22.2 lb eCO2/gal	2,682	0.36%
Natural Gas	mcf	247,746	0.12 lb eCO2/cf	14,865	2.01%
Jet Fuel	gal	68,206,543	21.1 lb eCO2/gal	719,579	97.34%
Total				**740,000***	

*Numbers may not add due to rounding

[37] BTS. Bureau of Transportation Statistics. Table C-16 Domestic Enplanements at U.S> Air Traffic Hubs.

[38] National Transportation Statistics 2006, Table 4-21; Bureau of Transportation Statistics: Washington, DC, 2006. http://www.bts.gov/publications/national_transportation_statistics/html/table_04_21.html

[39] Pittsburgh International Airport. Summary of Airline Traffic, December 2007. http://www.pitairport.com/UserFiles/File/stats/DECEMBER_2007_SHORT_E-MAIL_REPORT.pdf

[40] Energy Information Administration. Official Energy Statistics from the U.S. Government. Fuel and Energy Source Codes and Emission Coefficients.

[41] Kevin A. Gurchak – Manger of Environmental Compliance – Allegheny County Airport Authority (412) 472-3575

Airport Summary

As seen from Table 4.19 the emissions from PIT were determined to be roughly 740,000 tons of eCO2 for 2008. Note that the data behind this number came from actual provided information, and not estimates, so this value is most likely the much more appropriate estimate when compared to the value determined using Estimate 1. Also note that this estimate does not include electricity consumption, which was not provided. However, it can be assumed that electricity consumption at the airport is negligible since the jet fuel is shown to contribute over 97% of the emissions. Based on the two estimates used, Estimate 2 will be used to summarize the emissions from the airport, which can be estimated at 740,000 tons of eCO2.

4.9. Port of Pittsburgh Commission

The Port of Pittsburgh Commission (PPC) includes all freight transportation of cargo on the surrounding waterways in the Pittsburgh vicinity.

The ICLEI standard on Marine Transportation was consulted for guidance in how to allocate emissions from marine travel. According to the standard, fuel usage should be used as a way of allocating emissions to a certain port.[42]

The Port of Pittsburgh was unable to provide accurate fuel sales data, however the average trip length of transport as well as the average annual tonnage was provided. For the Ohio River System, the average trip length for cargo is 240 miles.[43] The average annual tonnage was reported as 42 million tons (2006), leaving the annual number of ton-miles at 10 billion.[44] It was assumed that all transport was done using barges, using 100% No. 6 residual fuel oil.

Using the annual ton-miles on the Pittsburgh river system, the energy intensity of barges was estimated to be 415 BTU/ton-mile.[45] After determining the total BTUs, an emission factor of 173.9 lbs eCO2/MBTU for No. 6 residual fuel oil was applied which was taken from the Energy Information Administration.[46] Using the factors above, the total emissions from transport of cargo was determined to be 360,000 tons eCO2 for the PPC.

Other sources of emissions that would be related to the PPC (buildings, other transportation, etc) were assumed to either be too small and therefore insignificant, or in the case of buildings,

[42] International Council for Local Environmental Initiatives (ICLEI), http://www.iclei.org
[43] Mark Brinza. Email and phone conversations. Port of Pittsburgh Commission. (412)-201-7333
[44] Port of Pittsburgh Commission. http://www.port.pittsburgh.pa.us/home/index.asp?page=1
[45] ORNL, 1999. Source taken from L.D. Maxim. Energy Requirements and Conservation Potential. http://tapseis.anl.gov/documents/docs/Section_4_9_May2.pdf
[46] Energy Information Administration. Official Energy Statistics from the U.S. Government. Fuel and Energy Source Codes and Emission Coefficients.

already counted in the commercial estimate for emissions. Other sources used for general knowledge include[47,48].

4.10. Port Authority (PAT)

The Port Authority of Pittsburgh contributes carbon emissions from two main sources, the bus system and the rail lines. Data for annual diesel fuel and electricity consumption was provided by a contact at the Port Authority[49] and is listed in Table 4.20. Energy use data for rail is split between the conventional rail and the two incline lines, the Monongahela and the Duquesne. The diesel fuel consumption for the bus system includes fuel required for maintenance vehicles and covers all service in the greater Pittsburgh area. The annual consumption data was multiplied by the emissions factors listed in the earlier sections to determine carbon emissions.

Table 4.20. Port Authority Fuel Consumption and Emissions

Service	Fuel Type and unit	Annual Consumption	Emissions (tons of eCO2)
Bus System	Diesel (gal)	8,160,000	90,576
Monongahela Incline	Electricity (kWh)	170,000	145
Duquesne Incline	Electricity	166,000	141
Rail	Electricity	29,660,000	25,211
Total			**116,073**

As seen in Table 4.20, the bus system contributes over 75 percent of the Port Authority's emissions. The conventional rail contributes around 20 percent with the rest covered by the incline lines. In summary, any mitigation efforts by the PAT should be directed at the bus system.

No attempt was made to allocate Port Authority emissions to trips directly attributed to City-related trips. Such an activity is beyond the scope of this report. Ideally, emissions should be spatially allocated by passenger miles. The Port Authority recently collected detailed ridership data for by route. This data could used to allocate emissions to City-related trips. We recommend the City and County coordinate to allocate PAT emissions for future inventories.

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[47] Texas Transportation Institute. National Waterways Foundation. Center for Ports and Waterways. A Modal Comparison of Domestic Freight Transportation Effects on the General Public. November 2007.

[48] Jim Corbett. Email correspondence. Associate Professor. University of Delaware College of Marine and Earth Studies.

[49] Email correspondence 02/13/09, Tia Gunn and Darcy Cleaver

5. Emissions of Cities Nationwide by Sector

5.1. Summary

In order to better understand the GHG emissions from Pittsburgh, it is important to be able to compare with other cities on a per capita basis. The GHG emissions from other major U.S. cities are initially found by analyzing documents on climate action plans associated with each particular city being analyzed. This initial method however was determined to not be the most effective way to compare the GHG emissions from each city since different methods were used when calculating the GHG emissions by each particular city. This led there to be a need for the 2003 inventory to include its own estimate for a selection of U.S. Cities. The approach to estimating the GHG associated with other cities is done on a broader scale than that of the estimate for Pittsburgh. The methods for estimation for each of the sectors in the different cities are described below.

5.2. Residential Emissions

The residential emissions for cities nationwide are estimated identically to the residential emissions of Pittsburgh. However, for other cities the regional RECS data varies, i.e. not all cities are located in the Middle Atlantic Region. Additionally, the electricity emissions factor is not constant from city to city. Table 5.1 lists all the cities for which the residential emissions were estimated as well as the assumed population, regional electricity emissions factor, and total residential emissions. The region specific emissions factors are given by the EIA.

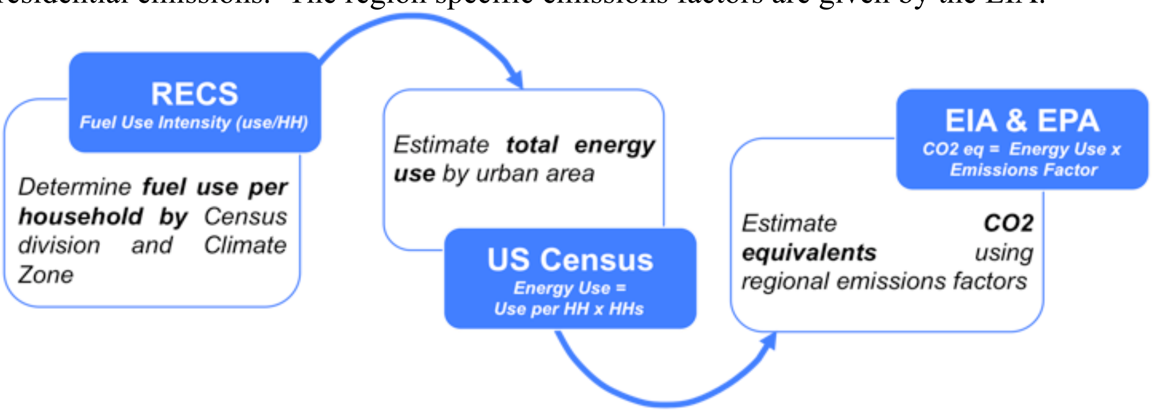

Figure 5.1. Methodology of Estimating Emissions from Residential Sector

5.1. Transportation Emissions

The greenhouse gas emissions associated with the transportation sector for various cities in the US were estimated using vehicle miles traveled data publicly available. This method is identical to the method used above to estimate the VMT for Pittsburgh. The Federal Highway Administration (FHWA) reports the daily vehicle miles traveled (DVMT) through the Highway

Statistics Report for different years[50]. For the year 2005, the table HM71 data was used, which contained population figures, road lengths (in miles) and DVMT estimates for different Federal-Aid Urbanized Areas within the US, as defined by the Bureau of Census. The miles and vehicle miles traveled data is segregated by type of road – namely, Interstate, Other Freeways and Expressways, Other Principal and Arterial, Minor Arterial, Collector and Local.

Table 5.1. Annual Residential Emissions of Cities Nationwide

City	Associated Electricity Emission Factor (lb eCO2/kWh)	Boundary Population	Total Emissions (million tons eCO2)	Per Capita Emissions (tons eCO2 per capita)
Pittsburgh	1.730	317,000	1.37	4.3
New York City	1.030	8,140,000	23.79	2.9
Chicago	1.410	2,840,000	11.42	4.0
Kansas City	1.528	445,000	2.25	5.1
Seattle	0.327	558,000	0.99	1.8
Los Angeles	0.773	3,840,000	6.87	1.8
Portland	0.327	650,000	1.09	1.7
San Francisco	0.773	739,000	1.73	2.3

The DVMT was converted to annual vehicle miles traveled totally for each urbanized area. This was allocated by population within city limits as reported by the US Census Bureau, to obtain VMT estimates for the different cities. Assuming that 8% of total vehicle miles traveled is contributed by trucks (single-unit and combination)[51], the total vehicle miles traveled within city limits was calculated.

Based on annual VMT, using fuel efficiencies and emission factors for each type of vehicle reported in the Transportation Energy Data Book[52], fuel consumption data and corresponding eCO2 emissions were calculated. The fuel efficiencies and emission factors for different types of vehicles, along with percentage of total VMT used for calculation purposes are summarized in Table 5.2.

The emissions associated with the transportation sector were estimated for different cities within the US, using the assumptions stated above. The annual total emissions and annual per capita emissions are reported in Table 5.3.

[50] Federal Highway Administration, Highway Statistics 2005, Table HM71 – *Urbanized Area 2005 – Miles and Daily Vehicle-Miles of Travel,* http://www.fhwa.dot.gov/policy/ohim/hs05/htm/hm71.htm
[51] The Transportation Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas, *Southworth Frank, Sonnenberg Anthon, Brown Marilyn A*
[52] Transportation Energy Databook 2007

Table 5.2. Fuel Efficiencies and Emission Factors for Vehicles

	% of total VMT	Fuel efficiency	Emissions Factors
		mpg	lb/gallon
Auto	92%	22.9	19.4
Single unit	4%	8.8	22.2
Combination	4%	5.9	22.2
Total	100%		

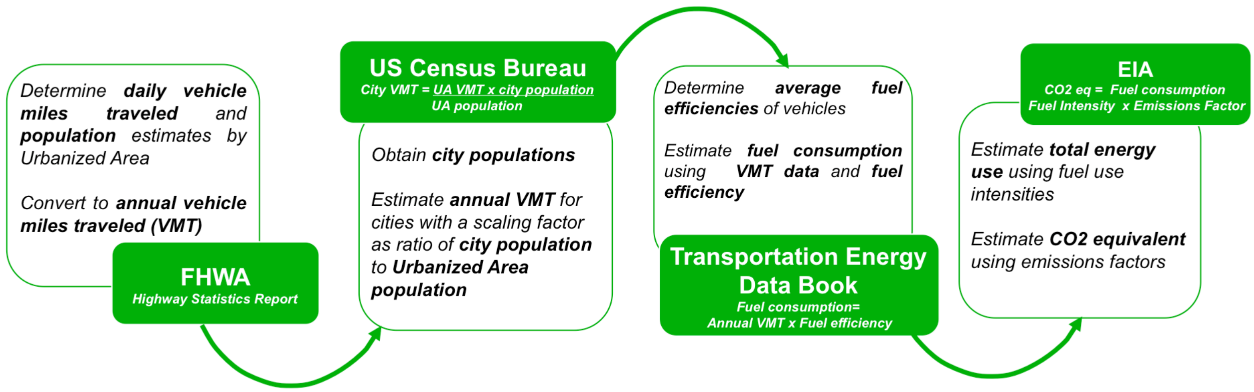

Figure 5.2. Methodology of Estimating Emissions from the Transportation Sector

Table 5.3. Transportation Emissions of Cities Nationwide

City	**Emissions (million tons-eCO2)**			
	Passenger Vehicles	**Trucks- Single Unit**	**Trucks- Combination**	**Total**
Pittsburgh	1.0	0.1	0.2	1.3
New York City	16.8	2.4	3.2	22.4
Chicago	8.8	1.2	1.7	11.7
Kansas City	1.9	0.3	0.4	2.6
Seattle	1.9	0.3	0.4	2.5
Los Angeles	12.5	1.7	2.4	16.6
Portland	1.6	0.2	0.3	2.1
San Francisco	2.5	0.4	0.5	3.3

5.2. Commercial Emissions

Five public data sources are used to estimate emissions associated with commercial buildings from cities nationwide:

1) EIA's Commercial Buildings Energy Consumption Survey (CBECS) for 2003 and 1999[53]
2) EIA's Residential Energy Consumption Survey (RECS) for 1997[54]

[53] Energy Information Administration (2009) Commercial Buildings Energy Consumption Survey. US Department of Energy. Accessed Feb-2009 http://www.eia.doe.gov/emeu/cbecs/

3) EIA's regional-level emission's factors for the period 1999-2002[55]
4) US Census 2000[56]
5) US Census American Community Survey for 2003[57]

The EIA CBECS 2003 summary tables are used to estimates fuel consumption factors (consumption per square foot of building space) by Census region, Census division, and climate zone (1-6). CBECS directly provides fuel consumption factors for electricity, natural gas, and total energy use. While natural gas and electricity constitute an overwhelming majority of total energy use, the difference is assumed to be fuel oil. Energy consumption factors are shown in Table 10.5 in the Appendix.

The 1999 CBECS summary data, 1997 RECS micro data, and US Census 2000 are used to estimate commercial to residential floor space ratios each Census division. The 1997 RECS data is used in lieu of more recent data because more recent RECS data sets did not estimate residential floor space. Residential floor space estimates were required because commercial floor space was estimated as a proportion of residential space by region, as summarized in Table 5.4. The 1999 CBECS data are used to temporally match the RECS data. Commercial to residential ratios are shown in Table 5.4.

Table 5.4. Commercial to Residential Floor Space Ratios

Census Division	Floor Space per HH in 1997 from RECS 97 (sq ft)	Total HH's from Census 2000	2000 Res Floor Space (mil sq ft)	CBECS 1999 Comm. Floor Space (mil sq ft)	Com to Res Ratio
East North Central	1,850	18,800,000	34,700	11,200	0.32
East South Central	1,510	7,320,000	11,100	5,220	0.47
Middle Atlantic	1,700	16,200,000	27,600	8,630	0.31
Mountain	1,530	7,540,000	11,600	4,580	0.39
New England	1,720	5,940,000	10,200	3,740	0.37
Pacific	1,400	16,800,000	23,500	10,200	0.43
South Atlantic	1,570	22,400,000	35,000	11,000	0.31
West North Central	2,010	8,210,000	16,500	5,560	0.34
West South Central	1,370	12,700,000	17,400	7,260	0.42

The 88 largest cities (not metropolitan statistical areas) reported by the US Census American Community Survey for 2003 are selected for emissions inventory. Selected cities range in population from approximately 65,000 (Sugarland, TX) to 8,000,000 (New York City, NY).

Each city is assigned a climate zone, a Census region, and a Census division based upon its geographic location. The CBECS climate zones are aggregates of climate zones defined by the

[54] Energy Information Administration (2009) Residential Energy Consumption Survey. US Department of Energy. Accessed Feb-2009 http://www.eia.doe.gov/emeu/recs/

[55] Accessed Feb-2009 http://www.eia.doe.gov/oiaf/1605/emission_factors.html

[56] US Census Bureau. Census 2000. Accessed Feb-2009 http://www.census.gov/main/www/cen2000.html

[57] US Census Bureau. American Community Survey 2003. Accessed Feb-2009 http://www.census.gov/acs/www/index.html

National Oceanic and Atmospheric Administration (NOAA). [58] Based upon these three geographic descriptors, the following factors are extracted from the above tables:

1) Square feet per household
2) Commercial to residential floor space ratio
3) Energy consumption factors for electricity, natural gas, and fuel oil
4) EIA electricity emissions factors

When assigning energy consumption factors to cities based on geography, the narrowest geographic resolution available is selected.

Once each city is assigned appropriate factors, the commercial energy consumption and emissions are estimated using the method summarized in Table 5.5.

Table 5.5. Commercial Emissions Estimates for Select Cities

City	Census Region	Census Division	Climate Zone	2003 HH's	Avg Sq Ft Per HH	Comm to Res Floor Space	Comm Floor Space (mil sq ft)
Pittsburgh	NE	Middle Atlantic	2	166,000	1,700	0.31	87.9
New York	NE	Middle Atlantic	2	3,250,000	1,700	0.31	1720
Chicago	MW	E North Central	2	1,150,000	1,850	0.32	685
Kansas City	MW	W North Central	2	211,000	2,010	0.34	143
Seattle	W	Pacific	3	280,000	1,400	0.43	169
Los Angeles	W	Pacific	4	1,350,000	1,400	0.43	814
Portland	W	Pacific	3	243,000	1,400	0.43	146
San Francisco	W	Pacific	4	354,000	1,400	0.43	213

City	Consumption Factors			Emissions					
	Electricity (kWh/sq ft)	Natural Gas (CF/sq ft)	Fuel Oil (1,000 gal/sq ft)	Elec Emis Factor (lbs eCO2 eq/kWh)	Electricity (tons eCO2)	Natural Gas (tons eCO2)	Fuel Oil (tons eCO2)	Total (mil tons eCO2)	Tons eCO2/ Capita
Pittsburgh	11.1	52.4	0.0	1.73	850,000	280,000	0	1.13	4.09
New York	11.1	52.4	0.0	1.03	9,900,000	5,400,000	0	15.3	1.94
Chicago	14.8	51.7	39.9	1.41	7,200,000	2,100,000	350,000	9.65	3.54
Kansas City	9.9	50.4	34.6	1.53	1,100,000	430,000	64,000	1.59	3.52
Seattle	14.5	33	88.9	0.33	400,000	330,000	190,000	0.92	1.74
Los Angeles	13.1	25.6	0.0	0.78	4,100,000	1,300,000	0	5.40	1.45
Portland	14.5	33	88.9	0.33	350,000	290,000	170,000	0.81	1.54
San Francisco	13.1	25.6	0.0	0.78	1,100,000	330,000	0	1.43	1.95

[58] http://www.eia.doe.gov/emeu/cbecs/climate_zones_explanation.html

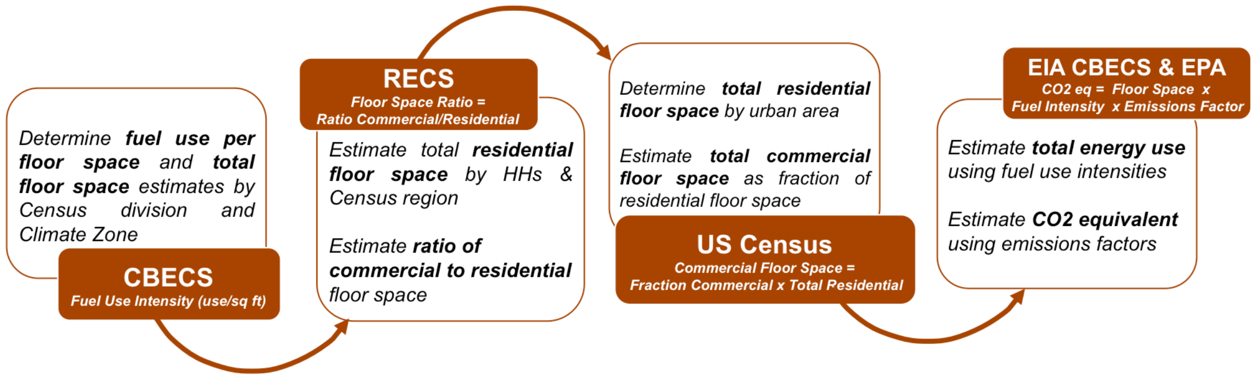

Figure 5.3. Commercial Estimate Methods Summary

5.3. Industrial Emissions

Using the estimation method described previously, the emissions of the industrial sector of various cities nationwide are determined. The United States 2003 GHG inventory report for the industrial sector is used along with population to scale down the emissions to the city level. The national average tons eCO2 per capita was determined using the US Census Bureau 2003 population. This per capita emission rate of 6.05 tons eCO2/capita is applied to the population of the selected cities to determine the total emissions associated with the industrial sector. The results can be seen in Table 5.6. The same problem arises of population and density within a city compared to the industrial activity in the same city. This can be seen especially in New York City, where there population is very high compared to the probable amount of industry. This results in a high overestimate of the industrial emissions being released within cities.

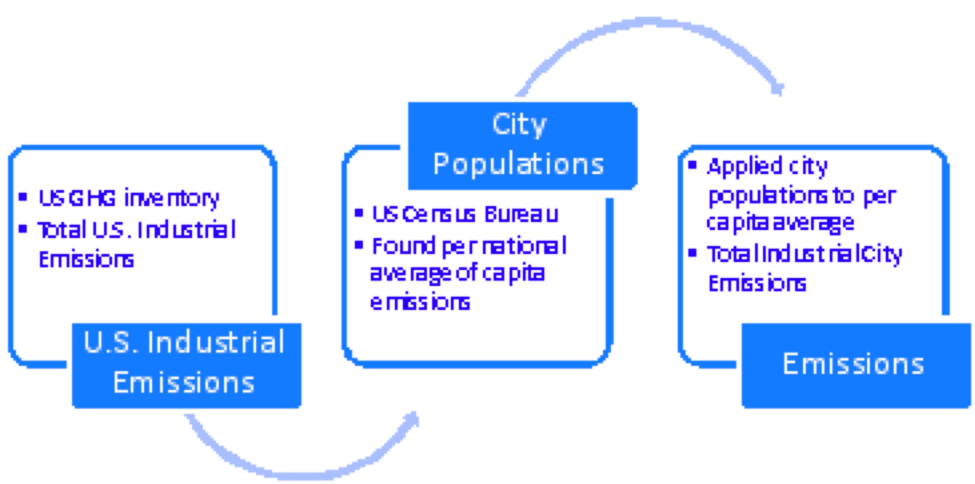

Figure 5.4. Methodology of Estimating Emissions from the Industrial Sector

Table 5.6. Industrial Emissions of Cities Nationwide

City	Boundary Population	Total Emissions Estimate (million tons eCO2)
Pittsburgh	317,000	1.70
New York City	8,140,000	44.70
Chicago	2,840,000	15.60
Kansas City	445,000	2.40
Seattle	558,000	3.10
Los Angeles	3,840,000	21.10
Portland	650,000	3.60
San Francisco	739,000	4.10

5.4. Airport Emissions

The GHG emissions associated with airports from other cities is estimated like that of the Estimate 1 method used in the PIT GHG emissions calculation. It is done by determining the number of enplanements for a given airport over the course of a year and assuming an average amount of fuel used per enplaned passenger. This method is not as accurate as having actual fuel data sold from each airport; however the amount of work needed for obtaining actual fuel use data from airports across the U.S. was outside the scope of this report. As seen from Estimate 1 estimate from the PIT section above, using the number of enplanements leaves a slightly higher estimate than knowing the actual fuel data. The two estimates are not significantly different however, and therefore estimating emissions based on number of enplanements can be used as a quick and simple way to estimate the GHG emissions from major airports across the U.S.

Table 5.7 shows the GHG emissions from a select number of airports across the U.S. The assumed 21 gallons of jet fuel per enplaned passenger was used again in this estimate.

Table 5.7. U.S. Airports Estimate

Airport	2006 Enplanements (millions)	Gallons of Jet Fuel Used (millions)	Emissions (million tons eCO2)
Pittsburgh	4.9	104	1.1
New York, NY (JFK)	21.1	443	4.7
New York, NY (La Guardia)	12.9	271	2.9
Chicago (Midway)	8.9	187	2.0
Chicago (O'Hare)	36.8	773	8.2
Kansas City	5.5	115	1.2
Seattle	14.7	309	3.3
Los Angeles	29.4	616	6.5
Portland	7.0	146	1.5
San Francisco	16.2	341	3.6

5.5. City Per Capita Emissions Comparison

The per capita emissions of the eight cities estimated in the 2009 inventory verification are compared with per capita emissions reported in Climate Action Plans published by each respective city. The initial goal was to determine how close the method used by the 2009 inventory verification on estimating other city's emissions came to the GHG emissions reported by each city in their respective Climate Action Plan. The per capita emissions are calculated by dividing the determined emissions for each city by the population of the city. The total per capita emissions are found to be similar in value. One difference however is that the industrial estimates in the 2009 inventory verification are much higher across all the cities than what was reported. This is expected, as it has been previously documented that the industrial estimation method possibly overestimates the sector emissions allocated to the city level. The residential, commercial and transportation per capita emissions seem to match fairly well for the cities. Figure 5.5 and Figure 5.6 show the per capita emissions for each of the cities studied.

5.6. Brookings Report

The Brookings Institution published a report in July 2001 on urban sprawl in the United States.[59] This report was analyzed when the 2009 inventory verification was being conducted, in order to try and determine if a correlation exists between the GHG emissions of a city and population density.

Figure 5.5 and Figure 5.6 show the per capita emissions for each of the eight U.S. cities analyzed. Figure 5.5 uses data from other cities inventories, while Figure 5.6 uses the data generated by the 2009 inventory verification using the methods previously described. The cities in the two figures below are arranged from left to right by increasing population. As seen, the density of the city's population is also shown on both figures. The density was obtained from the Brookings Report. As seen from both Figure 5.5 and Figure 5.6, there appears to be a correlation between the density of cities and the per capita emissions. Also, it is important to note that the per capita emissions determined by the individual cities seem to roughly correlate with the emissions that were determined for each city by the 2009 inventory verification methods.
The takeaway from the figures is that a city that is much more densely populated such as New York City is shown to generate fewer emissions per capita since there is likely to be more mass transit systems and closer living quarters resulting in less energy use per capita. While this may seem like an obvious assessment, it was confirmed by combining the data collected from the 2009 inventory verification and the Brookings report. From this assessment, it is important to realize that Pittsburgh may never be able to achieve per capita emissions levels approaching New York City even with extensive investments in lower emissions technology such as energy efficiency retrofits or mass transit systems. It is also important to realize that although the emissions per capita may vary greatly from city to city, it does not necessarily mean that one city has better or worse policy or environmental programs in place than the next city. The reason behind per capita emissions differences for cities could be more directly correlated with the

[59] The Brookings Institution. Center on Urban & Metropolitan Policy. Who Sprawls the Most? How Growth Patterns Differ Across the U.S. July 2001.

density of cities, rather than more conventional reasons such as geographical or differences in policy.

Figure 5.5 shows the per capita emissions obtained from other cities CAPs.

Figure 5.5. Per Capita Emissions Estimated by Individual City Inventories

Figure 5.6 shows the per capita emissions estimated using the 2009 inventory verification method. This method was done as part of this report in order to compare with values that were obtained using the CAPs of the actual cities.

Figure 5.6. Per Capita Emissions Estimated by 2009 Inventory Method

5.7. 2009 Inventory Verification Conclusion

The 2009 inventory verification was intended to produce an accurate GHG inventory for the city of Pittsburgh with specific steps and methods to follow so that inventories can be conducted more easily in the future for the city. It also aimed to verify and hopefully confirm numbers from the 2003 inventory. As seen from the methods and numbers described above, while the 2009 inventory verification did not use the same emissions factors or sources as the 2003 inventory, both quantitative estimates were relatively similar. The 2009 inventory verification has provided an accurate framework for future inventories to use when more updated sources become available.

In addition to making an estimate as the annual GHG emissions for Pittsburgh, this study also looked at how to implement recommendations for reduction as well as to measure the cost effectiveness of different reduction methods. In order to find common methods for reduction, other cities Climate Action Plans were utilized. This entire process is described in the remainder of the document.

6. **Climate Action Plans**

6.1. **Greenhouse Gas Inventories and Climate Action Plans**

There are already a lot of cities in the U.S. that have taken actions such as creating greenhouse gas inventories of their city emissions, instituting strong legislation to curb residents' behavior towards reducing emissions, and educating the public. However, to meet this pressing challenge before us, significantly greater action is needed from the local, state, and federal government levels.

In order for cities to set goals for the future, they first need to know where they stand on their greenhouse gas emissions inventory. Common practice for figuring out the current emissions level is to take a greenhouse gas inventory of the city. A greenhouse gas inventory is the total amount of greenhouse gases emitted into the atmosphere within a unit time frame (e.g. one year). The inventory illustrates which activities cause the most or least emissions, and thus shows the policy maker where the most potential for emissions reductions are. The inventory must also include background on the methods used to find quantities to input into the inventory. Of course, any inventory is an estimate and will only be as good as the data available. It is imperative that attention is paid when documenting where all data comes from for an inventory so that it can be transparently analyzed and also easily comparable to other cities. If a city wants to show how they have met their goals, they must perform incremental inventories, typically every two years. Proper documentation each year will make iterations easier and faster.

In order for most cities to be effective in reducing emissions, it is common to complete a greenhouse gas inventory and follow it with a Climate Action Plan (CAP). A climate action plan has been drafted without a greenhouse gas inventory, but an inventory is necessary to establish a starting point for reduction goals. A CAP will vary from city to city but serves the common purpose of stating a city's stance on climate change and what they propose to do to reduce their contribution to the problem. A CAP can be made by the city government or, like in Pittsburgh's case, made by a group of city organizations. More detailed CAPs will contain specific recommendations and the amount of eCO2 reduced by taking each action. Some CAPs prioritize their suggestions based on which will have the greatest effect; others go into detail regarding the cost of various mitigation actions. Reduction goals will be more likely to be met if CAPs are created every two years or so, in sync with inventories, in order to reevaluate what progress has already been accomplished and what future goals should be. More information regarding CAPs can be found in section 2. In addition to creating an inventory or CAP, there are higher level agreements cities can take part in to take a stand in reducing their emissions.

6.2. **U.S. Conference of Mayors Climate Protection Agreement**

On February 16, 2005 the Kyoto Protocol went into effect for the 141 countries that ratified it, agreeing to reduce their nations' emissions by various amounts depending on each country. It was that day that Seattle Mayor Greg Nickels initiated the U.S. Mayors Climate Protection initiative to advance the goals of the Kyoto protocol by local government even if the U.S. did not sign the agreement.

The agreement has three parts; the first is a pledge to "meet or beat" the Kyoto protocol's suggestion for the U.S. of 7 percent below 1990 levels by 2012 in their own communities. Actions to reduce emissions can range from anti-sprawl land-use policies to public information campaigns; from urban forest restoration projects to promoting the LEED rating system. The second part is a commitment by cities to urge their state and federal government to enact policies that can lead to carbon emissions reductions on the level of the Kyoto suggestion. The third part is a commitment to urge Congress to pass the bipartisan greenhouse gas reduction legislation, establishing a national emission trading system. President Barack Obama has welcomed congress to create such legislature, so support from these 900+ cities can aid in propelling this policy. As of March 27, 2009, 935 cities have signed on in all 50 states and Puerto Rico signed the U.S. Conference of Mayors' Climate Protection Agreement.

After a city signs this agreement saying that they understand the major issue at hand and want to make a change, the next step is to begin analyzing its emissions. Most cities can benefit from general guidance regarding what they should do. Fortunately, there currently are tools to help cities create greenhouse gas inventories and there are networks for cities to share ideas and recommendations.

7. Current Status of Inventories and Climate Action Plans in Cities

Multiple cities within the U.S. have initiated climate action plans (CAP) to structure a strategy to reduce the carbon footprint of their community. As of January 2009, 15 out of the 50 largest metropolitan regions of the U.S. have published formal publications outlining their CAPs on each city's corresponding environmental initiatives website available to the public. Due to the relatively nascent nature of efforts towards reducing carbon emissions, the level of detail among the CAPs range from broad and casual to scientific and aggressive. All CAPs estimate their city's emissions inventory to a certain degree of confidence; recommendations then follow that target possible areas to reduce the amount of emissions associated with those human activities. Despite the wide ranging approaches in developing emissions inventories and emissions reduction recommendations, there are strong trends that reveal the progress as well as gaps in the various cities' efforts to reduce greenhouse gas emissions.

Cities that have initiated a CAP cover every region in the U.S.: Northeast, South, Midwest, and the West. Clearly, the environment is a priority for communities across the nation. This section of the report analyzes the CAPs from the following cities: Boston, New York City, Philadelphia, Pittsburgh, Washington DC, Miami, Chicago, Kansas City, Houston, Denver, Seattle, Portland, San Francisco, Los Angeles, and San Diego.

Table 7.1. Cities Population and Emissions

City	Population	Emission Inventory (tons eCO2)
Boston	570,000	7
New York City	8,250,000	61.5
Philadelphia	1,500,000	15.1
Pittsburgh	310,000	6.6
Washington, DC	5,200,000	74
Miami	400,000	4.8
Chicago	2,800,000	36.2
Kansas City	440,000	9.9
Houston	2,200,000	1.97
Denver	550,000	14.6
Seattle	594,000	6.6
Portland	675,000	10.1
San Francisco	800,000	9.1
Los Angeles	4,000,000	51.9
San Diego	1,200,000	11.7

7.1. CAP Trends

There are many strong trends in the development of these CAPs. Nearly all of the cities are members of ICLEI's Clean Air Cool Planet initiative. Through this program, the cities had a standardized methodology to quantify their greenhouse gas emissions inventory and future projections. The CAPs also provide an introduction to the role of greenhouse gases and their impact on climate change. These leaders in environmental awareness and action show other communities how to identify the sources of the GHG and suggest recommendations on how to reduce them. Many of the CAPs goals and inspiration were drawn from the Kyoto Protocol, the Intergovernmental Panel on Climate Change, and other leading environmental efforts. There are four general strategies common among all CAPs:

- Energy efficient buildings
- Clean and renewable energy sources
- Improved transportation options
- Reduced waste and industrial pollution

Tackling climate change in such a grand scale is undoubtedly a major challenge, and its innate complexity is a source of inconsistency. Although a CAP is unique to each city's environment, reducing greenhouse gas emissions is a challenge that would benefit from a concerted effort from the country, and arguably the world. As multiple CAPs were analyzed and compared, a lack of consistency was noted. Below are several aspects of CAP designs that made things more difficult to compare and contrast the various climate action plans.

7.2. Time Frame

Consistent with the ICLEI CCP, different city CAPs have different target dates. Some cities have plans that are aiming to achieve their reduction goals by 2010; others have incremental goals through 2050. This variance compromises a united effort towards reduction goals. Setting up reduction goals with different target dates complicates the process of auditing the effectiveness of recommendations.

Table 7.2: CAP Target Goals and Years

City	Target Date	Target Emission Levels
Boston	2050	80% below 2007 levels by 2050
New York City	2017	30% below 2006 municipal levels
	2030	30% below 2005 city-wide levels
Philadelphia	2010	10% below 1990 levels
Pittsburgh	2030	20% below 2003 levels
Washington, DC	2012	10% below BAU levels
	2020	20% below 2005 levels
	2050	80% below 2005 levels
Miami	2015	municipal: 25% below 2007 levels
	2020	city: 25% below 2006 levels
Chicago	2020	25% below 1990 levels
	2050	80% below 1990 levels
Kansas City	2020	30% below 2000 levels
Houston	2010	11% below 2005 levels
Denver	2012	10% below 1990 levels
	2020	25% below 1990 levels
Seattle	2012	7% below 1990 levels
	2050	80% below 1990
Portland	2010	10% below 1990 levels
San Francisco	2012	29% below 1990 levels
Los Angeles	2020	35% below 1990 levels
San Diego	2010	15% below 1990 levels

7.3. Target Levels of eCO2 Reduction

Similarly, different cities have different target reduction goals. The levels of reduction are often based on targets as defined by the Kyoto protocol, but the CAPs often tailor the targets according to their city's ability to achieve such results, which leads to another inconsistency among the CAPs. For example, San Francisco has a short term reduction target of 20 percent below 1990 levels by 2012, while Kansas City has targeted a 30 percent emission reduction by 2020. Chicago has set up two target dates: 25 percent below 1990 levels by 2020 and 80 percent reduction by 2050.

Without detailed information describing the criteria in determining the target levels and dates of each city's CAP, there is a "black box" lack of transparency feeling in these published reports. For a city to declare an aggressive environmental initiative to reduce carbon emissions without completing a comprehensive quantitative analysis may be revealing a lack of understanding about the necessary steps to successfully implement climate action plans. It may further suggest that CAPs are being arbitrarily created and published more for political reasons than for environmental concerns.

7.4. Diverse Recommendations

The various CAPs overall compose a comprehensive observation of opportunities to reduce greenhouse gas emissions. It is noted that cities with different parameters and regional characteristics inherently have varying strengths and weaknesses. Analyzing different cities that all have their own unique set of circumstances to minimize climate change is understandable but consequently difficult to compare and contrast. Cities that are located near ideal wind and sun conditions have emphasized renewable energy use, while cities that are denser in population may have focused on retrofitting existing buildings to improve energy efficiency or developed programs to encourage mass transit. There is certainly reason to have emissions reduction recommendations that span across all industrial, commercial, and residential factors, but the ultimate goal is to analyze and determine which recommendations are most appropriate in terms of cost effectiveness, difficulty of implementation, and time length necessary. But without a standardized analysis and documentation of the effectiveness of recommendations, it is difficult for cities to collaborate and learn from other plans and improve its own.

One example of a recommendation to reduce emissions is retrofitting commercial and industrial buildings to reduce energy consumption. Chicago's CAP estimates that this action would reduce 1.3 million tons of carbon dioxide annually. This is an encouraging point of data, but it is not supported or detailed with 1) what specific retrofitting actions will be performed, 2) how effective each retrofit is in improving energy efficiency, 3) how many retrofits are estimated, or 4) how much each retrofit cost. This drawback unfortunately is common among all of the CAPs analyzed.

7.5. Cost of Recommendations

While estimate the cost of emission reduction recommendations may be the most difficult challenge, it is certainly one of the most important issues. With dozens of recommendations identified, cost effectiveness is a critical determining factor for recommendations. Again, this omission of information is common among all CAPs.

7.6. Behavioral Recommendations

While technical interventions and retrofits are more easily quantified, behavioral changes that reduce emissions have been included in CAP. Examples include increasing public transportation ridership, choosing to bike instead of drive, adjusting heating and air conditioning to more conservative levels, and driving more conservatively. These recommendations require changes to individual lifestyles and mentalities and are therefore more difficult to quantify and measure.

Programs have been developed to encourage behavioral changes. For example, schools often have programs to teach children to recycle at an early age and foster environmental awareness. Other behavior-based programs include other education and outreach programs, community informational signage, workplace programs and incentives, and implementing citywide incentive programs.

While the costs and effectiveness of behavioral interventions will be subject to considerable uncertainty, we recommend making reasonable assumptions to quantify behavioral recommendations when including them in CAPs. For example, a CAP action item that encourages additional public transportation could be defined by assuming an annual increase in ridership of 2% at an increased transit system operating cost of 1%. This would not only allow for quantification of costs and effectiveness but also provide actionable targets for the local transit authority.

7.7. Relevant Comparisons

In an effort to compare data across the multiple climate action plans, one relevant perspective is to look at the emissions per capita of the selected cities and compare them to Pittsburgh's number. Comparisons are displayed in Figure 7.1. The values shown in Figure 7.1 were taken from the GHG inventory published for each individual city.

According to Figure 7.1, the emissions per capita across the selected cities range from 10 – 25 tons of carbon dioxide equivalent, with an average of roughly 15 tons. This range is a consequence of many inputs, including population density, city government regulations, geographic environment, local industry, natural resources, and more. Denver leads all cities with the highest per capita emissions, likely due to the energy demand for heating needs. New York City had the lowest emissions per capita, likely due to its extremely high density and robust public transit system. It should be noted that the methods behind each cities estimate may be different which could also produce differing per capita emissions estimates. However, when the 2009 inventory verification analyzed an estimate on per capita emissions across the cities shown above and discussed in Chapter 5, similar results were found.

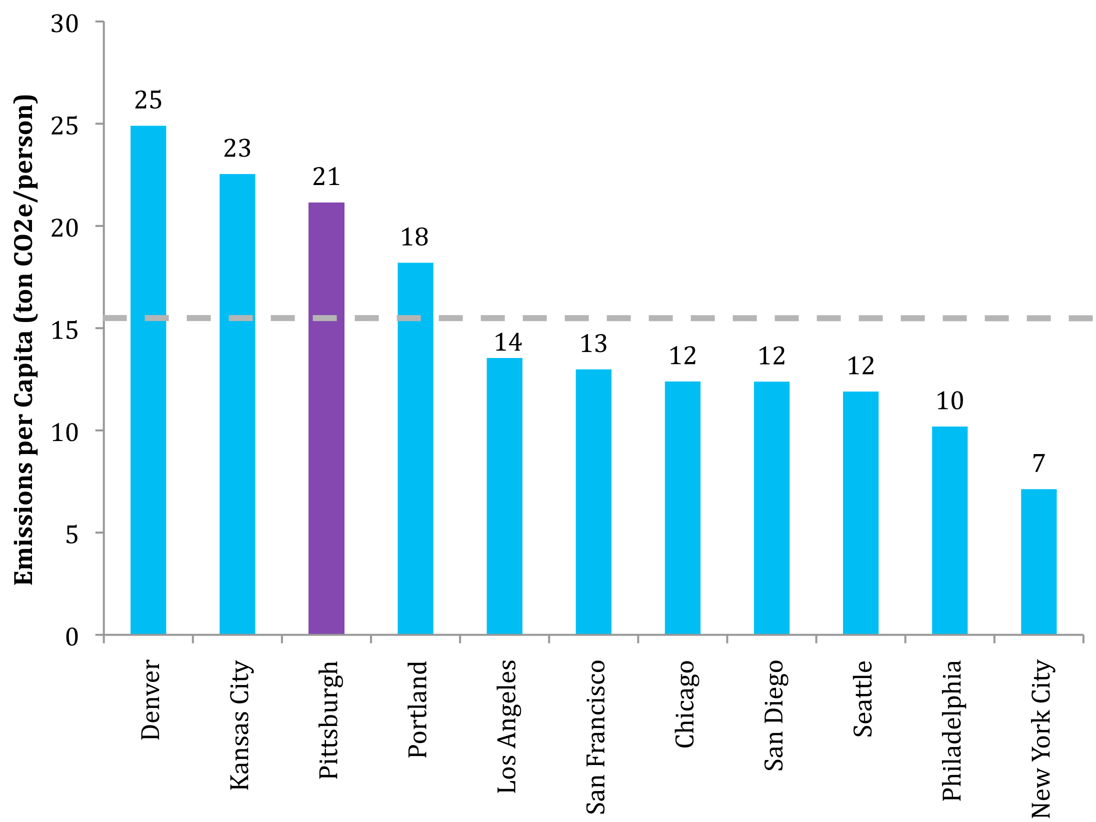

Figure 7.1. Emissions per Capita of Major US Cities.
Emissions taken from GHG inventories published by local authorities.

Pittsburgh's per capita emissions are approximately 21 tons of carbon dioxide equivalent, which is on the higher end of the spectrum. This reveals that while it may not be realistic for Pittsburgh to strive towards the same emissions targets as New York City, there are cities that are within range can serve as practical models in terms of emissions reduction plans.

From a different perspective, each city's emissions per capita can be broken down into emissions source by sector. As can be seen from Figure 7.2, some cities provided this level of detail to show if emissions came from the following sectors: Residential, Commercial, Industrial, Transportation, or Others. This data illustrates which sectors contribute the most emissions and allows decision makers the information as to where most emissions come from and potentially where the most reductions can come from.

One trend that this figure reveals is the level of consistency of the sectors. The transportation and industrial sectors are fairly stable across most of the cities while residential and others can fluctuate by several multiples of each other.

The eight cities on the left were reasonably divided into the five emissions sectors as indicated. Some of them split their emissions up unto these exact sectors while others were easily combined to approximate these sectors. These eight cities also have smaller or zero emissions in the 'Others' sector, indicating the ability to be allocated into the main sectors. The emissions of the five cities on the right side of the figure were difficult to allocate. These cities either did not break their emissions down, or they broke them down using a more uncommon method. Some of the cities lumped emissions into an 'electricity' or 'buildings' category, which creates problems in trying to allocate the emissions. These cities all had very high emissions in the 'Others' category due to this difficulty.

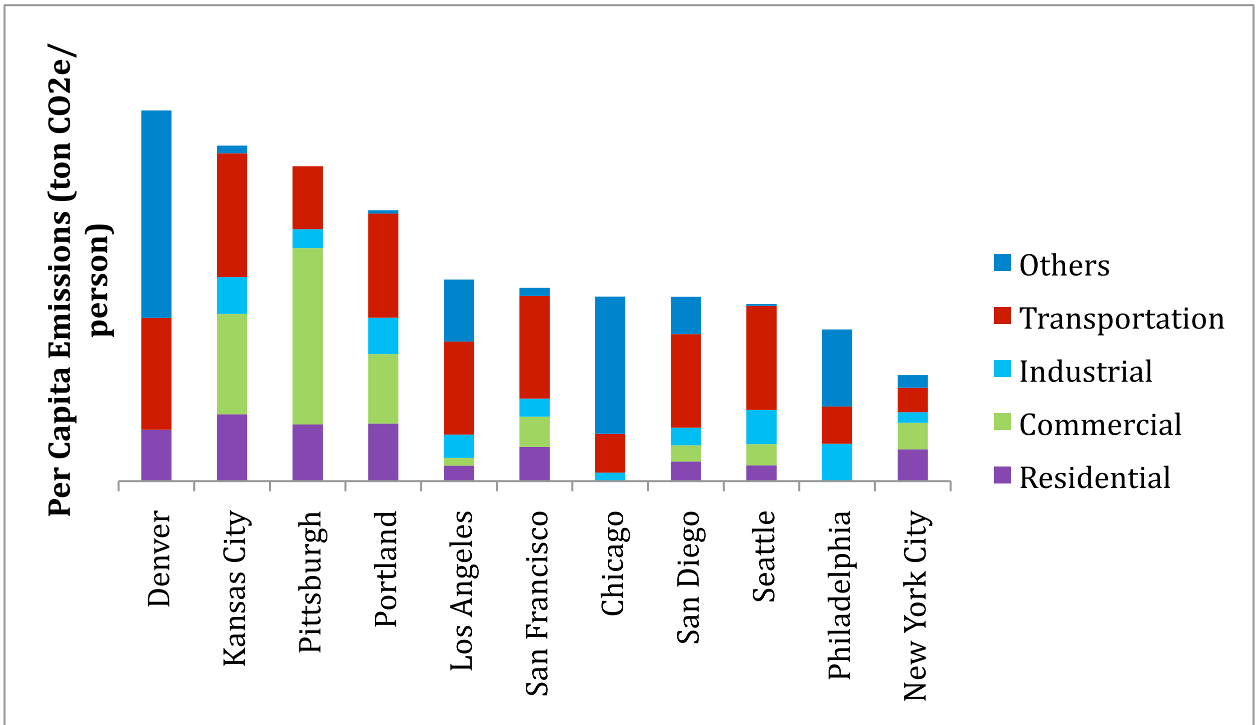

Figure 7.2: Emissions per Capita by Sector
Emissions taken from GHG inventories published by local authorities.

7.8. Primary Analysis

Since some cities have done some quantification of expected costs and/or mitigation for items in their CAPs, our intention was to use the work that other cities have already completed to understand how Pittsburgh could prioritize and implement GHG reduction strategies. Currently, Pittsburgh's Climate Action Plan is more or less a list of potential measures that could be implemented. There is no mention of how much of an impact even all of these measures taken together could have on our cities carbon footprint. We embarked with the intention of creating a more thoroughly documented plan of what we should and can prioritize. Thus, we decided to analyze as much data as we could find from as many cities as possible to determine which strategies were the lowest hanging fruit in terms of goal attainment (reducing our carbon footprint), cost effectiveness, administrative simplicity, and efficiency.

We began by looking at the 50 largest metropolitan areas in the U.S. We first narrowed our list down by eliminating metropolitan areas that did not have Climate Action Plans. We then narrowed our list further by choosing cities that had the most developed plans. For example, we found we could learn and borrow the most from plans that had quantified goals and strategies. What we found was that there was very little consistency across climate plans. Some plans attempted to define how much various measures could reduce greenhouse gas emissions. Some plans had taken a stab at determining the cost effectiveness and the payback period of the various strategies. A few attempted to understand how much cities would have to invest as compared to private citizens and companies. Some plans had conservative estimates of what percentage of people or companies they think would partake in each strategy. All of these elements were useful for our end goal.

Ultimately, we analyzed 12 cities in addition to Pittsburgh: Seattle, Los Angeles, Portland, San Diego, Denver, Chicago, New York, San Francisco, Kansas City, Washington DC, Miami, and Philadelphia. After selecting these cities, we performed two analyses of their emissions inventories. First, we looked at total emissions per capita, as demonstrated in our first graph. Second, we analyzed the emissions of each city. For example, how much of Pittsburgh's emissions come from transportation, or residencies, etc. Not all cities' inventories are organized in the same way so we used the info we had to align them as much as possible.

7.9. **Spreadsheet Explanation**

Once the list of city CAPs was compiled, further analysis of these action plans was conducted. An Excel spreadsheet was created to allow for the comparison between cities and to help estimate the effectiveness of the Pittsburgh CAP. The spreadsheet included the following information about all of the eCO2 reduction initiatives, 360 total, described in the twelve city CAPs:

- eCO2 reductions per year
- City population
- eCO2 reductions per capita per year
- Estimated cost spent
- Reduction initiative classification

Figure 7.3 provides a screenshot that illustrates the developed spreadsheet and the above column headers used to describes the city CAPs.

1 2	CAP CO2 Reduction Initiatives	Population	Reduction Initiative Classification	Reductions (tons CO2/year)	Reductions per Capit (tons CO2/person/yea
178					
179	**Houston (2,230,000)**				
180	LEED Building Certification and CHP in city facilities	2,230,000	Buildings - Construction Standards -	366,574	0.1
181	Citywide Lighting Retrofit	2,230,000	Buildings - Lighting - CFLs	7,806	0.0
182	Airport System's Energy Savings Initiatives	2,230,000	Buildings - Other	2,438	0.0
183	Retrofit city facilities	2,230,000	Buildings - Retrofits - City	27,472	0.0
184	Vending Machine Misers	2,230,000	Buildings - Vending Misers	212	0.0
185	Weatherization Program	2,230,000	Buildings - Weatherization	10,775	0.0
186	LED Traffic Signals	2,230,000	Energy - Lighting - LED Traffic Signa	13,960	0.0
187	Purchase wind energy	2,230,000	Energy - Renewable - Purchase	315,000	0.1
188	Recycling Program: City Facilities	2,230,000	Recycling - City	3,545	0.0
189	Recycling Program: Residential	2,230,000	Recycling - Residential		
190	City Vehicle Fleet Hybrid Initiative	2,230,000	Transportation - Alternative Vehicles -	1,741	0.0
191	City Employee Transit Program	2,230,000	Transportation - Public Transit - City	77	0.2
192					
193	**Kansas City (440,000)**				
194	Green Roofs	440,000	Buildings - Green Roofs	1,600	0.0
195	Million Lights Campaign	440,000	Buildings - Lighting - CFLs	40,400	0.0
196	Encourage businesses to reduce GHGs	440,000	Buildings - Other	46,200	0.1
197	Expand the City's Home Weatherization Program	440,000	Buildings - Weatherization	2,900	0.0
198	Traffic synchronization	440,000	Energy - Lighting - Control System	84,250	0.1
199	Reduce municipal energy use by 10%	440,000	Energy - Reductions - City	26,900	0.0
200	Purchase 5% of Municipal Energy from Renewable Powe	440,000	Energy - Renewable - Purchase	13,450	0.0
201	Education and public relations green choices campaign	440,000	Other	614	0.0
202	Reduce the use of polluting lawnmowers	440,000	Other	450	0.0

Figure 7.3. Screenshot of the CAP comparison spreadsheet

The twelve city action plans were thoroughly scanned and compiled into one spreadsheet with a total of 360 eCO2 reduction initiatives. However, only half of the initiatives included quantitative data about the projected or experienced eCO2 reductions per year, and none included data calculations. Furthermore, the range of CAP initiative eCO2 reductions was extremely broad. The smallest estimated reduction from any one initiative was 9 tons for Pittsburgh's recommendation to replace exit signs with LED lighting in the City Council Building. And the largest reduction estimate was 5,500,000 tons for implementing a solid waste reduction and recycling program in Los Angeles.

City population was inconsistently recorded across the CAPs; therefore, U.S. Census Bureau 2007 population estimates were used for all of the twelve cities. The eCO2 reductions per capita were calculated by dividing the eCO2 reductions per year by the 2007 city populations. This provides an estimate for the eCO2 reductions per person for each of the reduction initiatives, which is an important standardized metric for comparing cities of varying size. This is also relevant to the emissions per capita graph.

Lastly the spreadsheet included the reduction initiative classification column, and was designed to address the lack of consistency and standardization of the CAP reduction initiatives. All 360 of the recommendations were organized into one of the seven category headers listed below:

- Buildings
- Transportation
- Energy
- Recycling
- Water Conservation
- Urban Forestry
- Other

For example, a eCO2 reduction initiative such as "purchase wind energy," would be classified into the Energy category, and "Million Light Campaign," would be classified under Buildings. Additionally, each initiative was further classified using either one or two sub-categories. The sub categories provided a more detailed description about the initiative; therefore, the full classification for "purchase wind energy," was Energy–Renewables–Purchase, and was Buildings –Lighting–CFLs for the "Million Light Campaign." The overall classification system (which includes both the category headers and sub-categories) allowed the 360 eCO2 reduction initiatives to be organized into 38 unique categories.

Since multiple initiatives were classified under the same category, the mean, lower and upper bounds for the eCO2 reductions per capita were recorded for each of the 38 unique categories. Figure 7.4 shows a screenshot of the Excel file used to record this data.

	Reduction Initiative Classification	Per Capita (mt CO2/person)		
		Lower Bound	Upper Bound	Mean
3	Buildings - Appliances	0.10	4.0	2.04
4	Buildings - Construction Standards	0.17	0.08	0.13
5	Buildings - Construction Standards - City	0.0004	0.16	0.05
6	Buildings - Construction Standards - Commerical	0.54	0.54	0.54
7	Buildings - Construction Standards - Residential	0.28	0.28	0.28
8	Buildings - Efficiency - Residential	0.17	0.17	0.17
9	Buildings - Efficiency - Smart Meter	0.15	0.15	0.15
10	Buildings - Efficiency Standards	0.007	0.007	0.007
11	Buildings - Efficiency Standards - City	0.07	0.4	0.24
12	Buildings - Green Roofs	0.004	0.06	0.03
13	Buildings - Lighting - CFLs	0.004	0.15	0.08
14	Buildings - Lighting - LED Exit Signs	0.000028	0.000028	0.000028
15	Buildings - Office Equipment - EnergyStar	0.002	0.007	0.005
16	Buildings - Purchasing	0.007	0.007	0.007
17	Buildings - Retrofits	0.007	0.25	0.10
18	Buildings - Retrofits - City	0.0052	0.34	0.12
19	Buildings - Retrofits - Commerical & Industrial	0.46	0.46	0.46
20	Buildings - Retrofits - Residential	0.51	0.51	0.51
21	Buildings - Vending Misers	0.00006	0.0001	0.00008
22	Buildings - Weatherization	0.0048	0.0066	0.0057
23	Energy - Lighting - Control System	0.0029	0.25	0.15
24	Energy - Lighting - LED Traffic Signals	0.0027	0.0071	0.0054
25	Energy - Lighting - Street Lights	0.0042	0.019	0.010
26	Energy - Reductions - City	0.061	0.061	0.061
27	Energy - Renewable - Build	0.0071	8.8	2.1

Figure 7.4: Screenshot of the reductions per capita for each unique classification category

The above data in Figure 7.4 can then used to determine a mean, lower and upper bound on the total eCO2 reductions per capita that can be achieved if a city were to implement various combinations and types of reduction initiatives.

Using the other cities' quantified metrics and projections, a range was found to estimate the effectiveness of the recommendations. However, only the recommendations that included numbers could be analyzed with accuracy as reliable as the data published in the climate action plans. It is noted that all estimates are dependent on multiple variables that affect the transferability of other data to Pittsburgh, such as climate or scale, were largely discounted. The objective was to understand the order of magnitude of investment and benefits of the reduction recommendations; furthermore, this step serves as a stepping-stone for generating fresh, documented numbers for recommendation reductions. The following section describes how this data was used to provide an estimate for the potential effectiveness of Pittsburgh's CAP.

7.10. Estimating the Emissions Reductions of Pittsburgh

The classification system that was developed can be used for various analyses of the climate action plans. The first analysis that was looked at was applying the classification system to Pittsburgh's current climate action plan. By doing this, we were able to develop an initial estimate of Pittsburgh's emissions reductions based on the current CAP. Comparing this estimated reduction with the overall inventory will give an idea of how Pittsburgh is doing in terms of meeting its emission reduction goals. Figure 7.5 is a sample of the Pittsburgh estimated reductions worksheet.

	A	B	C	D	E	F
1	**Pittsburgh (312,819)**			**Min**	**Max**	**Median**
2	LEED Construction Standards for Municipal Buildings	Pittsburgh	Buildings - Construction Standards - City	0.000	0.164	0.047
3	Create incentives for Green Roofs	Pittsburgh	Buildings - Green Roofs	0.004	0.060	0.032
4	Replace Exit Signs with LED lighting	Pittsburgh	Buildings - Lighting - LED Exit Signs	0.000	0.000	0.000
5	Adopt GreenPrint Software & Duplex Printing	Pittsburgh	Buildings - Office Equipment			
6	Build a Green Arena	Pittsburgh	Buildings - Other			
7	Implement Retrofits	Pittsburgh	Buildings - Retrofits - City	0.005	0.340	0.119
8	Install Vending Misers	Pittsburgh	Buildings - Vending Misers	0.000	0.000	0.000
9	Upgrade Lighting at City Parks and Sports Fields	Pittsburgh	Energy - Lighting - Control System	0.003	0.250	0.149
10	Install LED Traffic Signals	Pittsburgh	Energy - Lighting - LED Traffic Signals	0.003	0.007	0.005
11	Retrofit Mercury Streetlamps w/ Efficient Models	Pittsburgh	Energy - Lighting - Street Lights	0.004	0.019	0.010
12	Encourage Solar energy use with Incentives	Pittsburgh	Energy - Renewable - Build Solar	0.044	0.044	0.044
13	Purchase Renewable Energy	Pittsburgh	Energy - Renewable - Purchase	0.000	0.290	0.087
14	City Recycling Program	Pittsburgh	Recycling - City	0.002	0.043	0.016
15	Create City Operated Compost Facility	Pittsburgh	Recycling - Compost			
16	Methane Recovery	Pittsburgh	Recycling - Methane Recovery	0.007	0.380	0.085
17	Establish Pay-As-You-Throw policies	Pittsburgh	Other			
18	Biodiesel for Public Transportation	Pittsburgh	Transportation - Alternative Fuel - Public Transit			
19	Encourage Retail Stations to supply B5 fuel	Pittsburgh	Transportation - Alternative Fuel - Supply			
20	Incorporate Alternative Vehicles into City Vehicle Fleet	Pittsburgh	Transportation - Alternative Vehicles - City	0.001	0.008	0.004
21	Anti-Idling Laws	Pittsburgh	Transportation - Anti-idling	0.000	0.000	0.000
22	Install Bike Racks & Creat Bike Program	Pittsburgh	Transportation - Biking	0.000	0.004	0.005
23	Increase Bike Racks on Buses	Pittsburgh	Transportation - Biking	0.000	0.004	0.005
24	Establish Congestion Fees	Pittsburgh	Transportation - Fees			
25	Plant Trees	Pittsburgh	Urban Forestry - Tree Planting	0.002	0.077	0.023
26	Install Variable Freq. Drives at Water and Sewer Authority	Pittsburgh	Utilities			
27	Thermostat adjustments at universities	Pittsburgh	Other			

Figure 7.5. Sample of Pittsburgh's Estimated Reductions Worksheet

The first column is a list of the actions that were listed in the CAP. The whole unfiltered list of actions was initially listed. We then went through and identified which ones had one of the classifications associated with it. The rest were filtered out to come up with the sample spreadsheet shown above in Figure 7.5. These represent the actions that were seen as quantifiable and able to be classified. A lot of the filtered out actions were non-quantifiable actions specific to the city, such as hiring a certain person at the city building. Columns D, E, and F show the Min, Max, and Median values of the estimated emissions reductions per capita for the given classification of action. This data has the unit of tons of eCO2 reduced per person.

These individual classification per capita reduction numbers were summed to find the Min, Max, and Median per capita reduction estimates for Pittsburgh's quantifiable CAP actions. These results showed a maximum per capita reduction for Pittsburgh of 1.7 tons of eCO2 per person. Looking back at Pittsburgh's greenhouse gas inventory, it showed overall emissions of 17.3 tons of eCO2 per person. This initial analysis shows that Pittsburgh completing all of their quantifiable actions would reduce their footprint by a maximum of approximately 9.7%. This reflects the upper-bound (maximum data column) estimate of the reduction. While there is significant variation in that estimation, it reveals the weaknesses of the current generation of CAPs as a tool to help make decisions and policies.

The above estimate of Pittsburgh's reductions does consider city population by estimating based on per capita numbers. The most variable aspect that is not accounted for is project scale. For each individual classification of action, there are multiple examples of the action with varying scales. Pittsburgh's action for the Buildings – Retrofits – City classification involves applying building retrofits to only one government-controlled building. Meanwhile, other cities that have a Buildings – Retrofits – City action could be referring to completely retrofitting a large number of government buildings. This observation means that a method has to be created that factors in all of the important characteristics to an action's effect. This includes factors such as population and scale, as has been discussed.

This analysis only accounts for the planned actions of Pittsburgh based on the published CAP. It does not consider any actions that have been undertaken or will be done that are not published in the CAP. This is interesting to note because it brings up an additional variable that exists between all of the CAPs of various cities. The degree of detail to which a city includes actions will affect their overall reduction numbers. One city might routinely do 'energy blitzes' to get households to reduce energy use. Since they have historically done this action they might not include it in their CAP. Meanwhile, a city just implementing an 'energy blitz' system might include it as an action in their CAP. This would mean that while both cities are reducing their emissions because of the same action, it is only accounted for in one of the CAPs. Looking at CAPs of other cities will have the positive effect of identifying actions that are already taking place in a city that they may not be accounting for in reductions estimates.

8. Description and Calculations of Action Items

Building off of Chapter 7, the 360 recommendations analyzed in other cities' CAPs were scrubbed down to a more manageable list of quantifiable recommendations for Pittsburgh. Recommendations that were unique to individual cities and might have been difficult to implement in Pittsburgh were removed. Also, any recommendation that was subject to behavioral participation was removed as it would be difficult to project participation for any implemented item. Only those recommendations that could be quantified without taking into account who might actually participate were analyzed for their cost effectiveness. Examples include replacing all street lights with LED lights, or replacing the city vehicle fleet with hybrid vehicles. In the end, this list became a list of just over 30 action items. These items were looked at extensively and the calculations and assumptions behind the cost effectiveness numbers for each recommendation are described below.

8.1. Public Transit

Recommendation 1:

The introduction of hybrid electric buses in the public transit system of any city could result in lowered eCO2 emissions. The calculations to find the cost effectiveness (or the cost per ton reduction of eCO2) are described in the paper, "Does Rail Transit Save Energy or Reduce Greenhouse Gas Emissions?"[60] Assuming a capital cost of $500,000 per hybrid bus introduced[61], this cost is annualized at a discount rate of 4% over an average lifespan of 10 years. The annual diesel fuel savings reported in the paper is 2000 gallons/year. At a price of $2.75/gallon of diesel fuel, this translates to fuel cost savings of about $5500/year. Further, using an emissions factor of 22.2 lbs/gallon for diesel combustion, the eCO2 reductions are about 22 tons for a hybrid bus introduced. The cost effectiveness is calculated as the ratio of the annualized costs to the eCO2 savings and is approximately $2500/ton reduced.

Table 8.1. Hybrid Electric Bus Summary

Capital cost	500,000	$
Life span	10	years
Discount rate	4%	
Fuel savings per year	2000	gal/year
Fuel saving costs	5500	$/year
Annualized costs	56145	$/year
eCO2 savings	22	tons/year
Cost/ton eCO2 reductions	2529	$/ton

[60] Does Rail Transit Save Energy or Reduce Greenhouse Gas Emissions?", Randal O'Toole, Policy Analysis No 615, April 14, 2008
[61] http://www.hybridcenter.org/hybrid-transit-buses.html

Recommendation 2:

The National Transit Database (2007) reports characteristic data for major transit agencies across the country. The following data for motor buses, owned by the Port Authority Transit (PAT) in Pittsburgh, is obtained from the NTD[62].

Table 8.2. Port Authority Motor Bus Operations Data for 2007

Category	Amount	Units	Source
Number of vehicles	813		table 17, NTD 2007
Diesel consumption	8,824	thou gal	table 17, NTD 2007
Annual VMT	35,600	thou miles	table 19, NTD 2007
Annual passenger miles	288,379	thou pass-miles	table 19, NTD 2007
Number of passengers/bus	8		

The average number of passengers per motor bus is calculated as the ratio of the total annual passenger-miles, to the total annual VMT and this is approximately 8. The annual VMT per bus is calculated by dividing the total annual VMT by the total number of buses. The total diesel consumed per bus annually is calculated as the ratio of the total diesel consumption to the number of buses. The average diesel consumption per mile by a single motor bus is estimated as the ratio of the annual diesel consumption by the annual miles traveled per bus. These values are reported as follows.

Table 8.3. Average Port Authority Bus Mileage and Fuel Consumption

Total miles driven	43,788	miles/year
Total fuel consumption	10,854	gallon/year
Fuel consumption per m	0.25	gallon/mile

Another recommendation is the introduction of smaller capacity vehicles to run during off-peak hours and low frequency routes. Using the method of estimation proposed in the Randal O'Toole paper, for the Portland Tri-Met Transit Agency, it is suggested that a 15-passenger bus be introduced into the PAT system, to account for 1/3rd of miles traveled by a single existing large bus. The average number of passengers per bus remains the same. The cost of this bus is estimated to be $50,000[63]. Assuming, as stated in the paper, that these buses consume 40% as much fuel as the large buses, the consumption rate for smaller buses is estimated to be 0.1 gallons/mile. Therefore, the total fuel consumption using large buses for 2/3rd and the smaller bus for 1/3rd of the total miles traveled originally per large bus is as shown below.

Table 8.4. Smaller Capacity Public Transit Bus Performance

	Large bus	Small bus	Total	Unit
Total miles driven	29192	14596	43788	miles/year
Fuel consumption per mile	0.25	0.10		gallons/mile
Total fuel consumption	7236	1447	8683	gallons/year

[62] http://www.ntdprogram.gov/ntdprogram/pubs/dt/2007/DataTables07TOC.htm

[63] Transportation Equipment Sales Corp., "New Shuttle Bus Inventory for Sale" (Oregon, OH:TESCO, 2007), tinyurl.com/2zuscj

The decrease in fuel consumption due to the introduction of smaller buses is calculated as 10854 gallons/year – 8683 gallons/year = 2171 gallons/year.

The emissions reductions due to diesel fuel savings are calculated using an emissions factor of 22.2 lbs/gallon. Further, at a price of $2.75/gallon of diesel fuel, the cost savings due to reduced fuel consumption are also accounted for. Using a discount rate of 4% and a life span of 10 years, the capital costs are amortized over the lifetime of the bus and the annualized costs are calculated, including the savings incurred due to reduction in fuel consumption. The cost effectiveness of this method is calculated as the ratio of the annualized costs to the annual emissions reductions observed and is estimated to be around $8/ton eCO2 reduced.

Table 8.5. Smaller Capacity Bus Summary

Capital cost	50,000	$
Life span	10	years
Discount rate	4%	
Fuel savings per year	2171	gal/year
Fuel saving costs	5969	$/year
Net costs incurred	195	$/year
eCO2 savings	24	tons/year
Cost/ton eCO2 reductions	8	$/ton

The number of PAT buses in operation is reported as 813, by the National Transit database. Therefore, it is assumed that the maximum number of hybrid buses or smaller buses that can be introduced is around 800. This serves as a maximum constraint for optimization purposes.

8.2. LED Traffic Lights

Many cities across the world are currently looking to or already have replaced standard incandescent traffic signals with more energy efficient and longer lasting LED lights. In the summer of 2008, the City of Pittsburgh retrofitted all traffic signals and crosswalks with LEDs The cost of the project is expected to total nearly $2 million, but save the city roughly $325,000 annually through decreased electricity use. Each intersection is said to use 80% less energy when equipped with LEDs[64]. The lifetime of LEDs are expected to last at least five years with an expected life of 7-10 years. The current incandescent fixtures are changed annually. In addition to energy savings, the LEDs will save a tremendous amount of money on city maintenance.[65]

Existing incandescent bulbs for traffic signals are estimated to be $2.50 per bulb and are 150 watts each. The newer LEDs range from 10-20 watts depending on the color and cost at least $50 per replacement fixture. The installation and labor costs of LED traffic signals are estimated to be $150 per traffic signal[66].

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[64] Pittsburgh Business Times. CLT Efficient Technologies Group. http://www.bizjournals.com/pittsburgh/stories/2007/10/01/focus4.html

[65] Program Requirements for Traffic Signals. Energy Star. http://www.energystar.gov/ia/partners/product_specs/eligibility/traffic_elig.pdf

[66] City of Portland Oregon. Energy Efficient Success Story. http://www.portlandonline.com/shared/cfm/image.cfm?id=111737

The standard traffic signal containing three 150 watt bulbs will consume roughly 1,300 kWh per year, assuming one light is always on. An LED stoplight will use about 100 kWh per year. The 1,200 kWh savings is equivalent to the reduction of nearly one ton of eCO2 annually per traffic signal. At an initial investment of $150, this means the cost effectiveness of retrofitting traffic signals with LEDs is about $150/ton of eCO2 reduced.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Knowing that the initial retrofit will cost $150, LED traffic lights are assumed to have a seven year life cycle. When comparing to standard incandescent bulbs in traffic lights, which are replaced every year, there will be cost savings every year for seven years. Using an electricity cost of $0.10 per kWh, roughly $120 will be saved per traffic signal in just energy costs alone. There is also a maintenance savings of not having to change the lights on an annual basis, however due to variability in maintenance costs, it is not calculated here. The seven year lifecycle means that seven tons of eCO2 are mitigated over the lifetime of the new traffic signal. The annualized cost effectiveness is determined to be -$95/ ton eCO2. The results of implementing LED traffic signals are displayed in Table 8.6.

Based on 800 intersections throughout the city, and assuming at least four traffic signals per intersection, the max constraint of replaceable traffic signals would be at least 3200 units.

Table 8.6. LED Traffic Signals Summary

Capital Cost	$150	Per traffic signal (3 bulbs)
Life span	7	years
Discount rate	4%	
Energy Savings per year	1,200	kWh/year
Energy savings cost	$120	Per year per signal
Annualized costs	-$95	Per year per signal
eCO2 savings	1	Tons/year per signal
Annualized $/ton eCO2 reduced	-$95	$/ton

8.3. LED Street Lights

LED street lights are another emerging technology being implemented in cities across the world. Cities that have already implemented LED street lighting include Ann Arbor, MI, Toronto, Canada, and Raleigh, NC. Ann Arbor is spending $630,000 to retrofit street lights in the downtown area with LEDs[67]. The LEDs use 56 watts compared to the 120 watts currently used in the street lights in Ann Arbor. In total, Ann Arbor will retrofit 1,046 lights, each costing about $600 per street light to replace with LEDs. The electricity savings will be nearly 50%.

Los Angeles is also embracing LED street light technology and implementing a city-wide retrofitting project set to begin in June 2009. LA will install nearly 140,000 LED street lights at a cost of $57 million. The installation cost per street light for the project is about $400[68].

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[67] LED Magazine. Ann Arbor. October 2007. http://compoundsemiconductor.net/blog/2007/10/ann_arbor_embraces_led_technol.html

[68] Environmental Leader. LA Launches Nations Biggest Lighting Retrofit Program. http://www.environmentalleader.com/2009/02/19/la-launches-nations-biggest-lighting-retrofit-program/

The energy utilization and payback analysis for LED street lights is done for one street light and can be scaled up accordingly. It is assumed that implementing LED street lights will cost $500 per light. This value is based on previous cities implementation programs, but may fluctuate based on labor and material costs for a given location[69]. This value is also within the range of four LED street lighting technologies implemented in a Department of Energy (DOE) study on LED street lights in San Francisco, CA[70].

It is also assumed that street lights are in operation 11 hours per day, or roughly 4,000 hours per year. The hours of operation will also be unique to a given location. It should be noted that the DOE study previously mentioned used a value of 4,100 hours for annual operation. This same study used four different types of LED street lights which each used anywhere from 41 watts to 69 watts per fixture. It will be assumed that a newly installed LED street light fixture will use 60 watts, replacing high pressure sodium (HPS) lights using 138 watts per fixture. From the above assumptions, each street light will save 312 kWh annually.

According to the DOE study, manufacturers of LED luminaries supplied predicted lives estimates for LED street lights ranging from 50,000 hours to more than 100,000 hours (a lifetime of 12 to 25 years using 4,000 hours per year). These lifetimes are found to be significantly longer than that of HPS lights, rated with a life of about 30,000 hours or 7.5 years. Although it is not feasible to predict that a lamp will last for upwards of 30 years without any maintenance, it should be noted that LED street lights will last significantly longer than HPS street lighting before needing maintenance. To account for the possibility of catastrophic failure, or other unforeseen circumstances, the DOE study assumed a lifetime of 16 years for LED street lighting. Note that this value could be longer or shorter depending on different LED technologies, location, climate, as well as wear and tear on the system. For this calculation, it will be assumed that the LEDs will last twice as long as current HPS lighting or about 16 years. The DOE study estimates a replacement cost for HPS fixtures of roughly $100. Assuming HPS lights would be replaced twice over the lifetime of the LED lights, the total lifetime savings can be determined.

The eCO2 emissions reduction would be a result of the decreased electricity usage. Using the electricity emissions factor for Pittsburgh (1.7 lbs eCO2/kWh), each street light would reduce eCO2 emissions by roughly four tons over the lifetime of the light. The annualized cost per ton reduction of eCO2 was determined to be about $52/ton eCO2.

There are approximately 40,000 street lights in the city of Pittsburgh. At an installation cost of approximately $500 per light, this would mean a total project cost of about $20 million for the city of Pittsburgh to retrofit all of the existing street lights with LED technology. Electricity savings to the city alone would be more than $1 million per year[71]. It is estimated that the city spends $1 million yearly in maintenance costs for the street lights which could be reduced by as much as 75%. Roughly speaking, Pittsburgh therefore could recognize savings of more than $1.5 million yearly in electricity and maintenance costs using the assumed values above. The

[69] Best Home LED Lighting. Cost of LED Street Lighting. http://www.besthomeledlighting.com/page/led_street_light?gclid=COrgjv2QppkCFQECGgodRzREpQ
[70] http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_sf-streetlighting.pdf
[71] http://www.ledinside.com/Pittsburgh_and_San_Jose_start_converting_street_lights_to_LEDs_20090212

results of implementing LED street lights are displayed in Table 8.7. The max constraint for LED street lights is 40,000.

Table 8.7. LED Street Light Summary

Capital Cost	$500	Per street light
Life span	16	years
Discount rate	4%	
Energy Savings per year	300	kWh/year
Energy savings cost	$30	Per year per light
Annualized costs	$13	Per year per light
eCO2 savings	0.25	Tons/year per light
Annualized $/ton eCO2 reduced	$52	$/ton

8.4. LED Exit Signs

Using LED exit signs are an easy way to reduce the electricity usage in a building. Since exit signs use electricity 24 hours per day, any reduction in the watts used will lead to significant energy savings. The standard exit sign utilizing two incandescent bulbs uses 350 kWh annually. An LED exit sign uses 44 kWh annually[72]. Using a cost of electricity of $0.10/kWh, a savings of about $30 per year in electricity costs is determined. LED lamps have an expected life of more than ten years. Regular incandescent lamps have an expected life of only three months. The savings per year in material and labor costs is assumed to be $10 per sign.

LED exit signs can be purchased for about $20[73], plus a labor fee of installation assumed to be $50 per sign. Using this $75 initial installation cost of replacing an exit sign with an LED sign and the kWh reduction shown above, LED signs will save roughly 0.2 tons of eCO2 per sign annually. The annualized cost effectiveness is determined to be -$135/ton eCO2.

The original Pittsburgh Climate Action Plan estimated there to be 60 exit signs in city owned buildings[74]. Based on this estimate, an investment of $1,200 would cover the purchase price of 60 exit signs while reducing the electricity usage by $1,800 per year. Note that this savings is in electricity alone and does not include maintenance and replacement savings of new bulbs for the regular exit signs. The summary features of implementing LED exit signs are displayed in Table 8.8.

The max constraints for the city of Pittsburgh to replace all exit signs would be roughly 60,000 signs. This number was estimated utilizing the estimate of 60 million square feet of floor space in the city, and assuming one sign per 1000 square feet. The max for the municipal buildings is estimated to be about 1000 signs.

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[72] Save Energy, Money, and Prevent Pollution. Energy Star. http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheet.pdf

[73] Cost of Exit Sign. 1000 bulbs. http://www.1000bulbs.com/Exitronix_Emergency_Light_Fixtures/Exit_Lights/31463/?&utm_source=Froogle&utm_medium=shopping+site&utm_campaign=Froogle+datafeed

[74] Pittsburgh Climate Action Plan. Version 1.0. Replace Exit Signs in City Buildings. Pg 19.

Table 8.8. LED Exit Sign Summary

Capital Cost	$20	Per exit sign
Life span	10	years
Discount rate	4%	
Energy Savings per year	300	kWh/year
Energy savings cost	$30	Per year per sign
Annualized costs	-$28	Per year per sign
eCO2 savings	0.2	Tons/year per sign
Annualized $/ton eCO2 reduced	-$140	$/ton

8.5. House Weatherization

House weatherization reduces home heating bills by about 30%, and results in savings of about $350 in total annual energy bills.[75] Not only can a lot of money be saved through weatherizing a house, but the reduction in CO2e emissions is also substantial. An average home was modeled and specific energy saving weatherization techniques were used to determine the total capital cost of improvements, the annual savings in energy costs, as well as the cost per ton of eCO2 reduced. The energy saving techniques include attic floor insulation, weather-stripping of windows and doors, caulking of windows and doors, water heater insulation, and hot water pipe insulation. These were chosen because they are all low cost alternatives that are can easily be done by the average homeowner.

Assumptions

The costs of each of these energy saving techniques were determined by a local provider of home improvement goods. These unit costs were applied to the assumptions in Table 8.9 to determine the total cost of weatherizing a house, about $570. The reduction in emissions and energy was then calculated using known savings in cost and energy. It was assumed that the window, door, and attic techniques are directly related to natural gas energy savings, while the hot water pipes and water heater technologies are directly related to electricity energy savings. This was assumed because Pittsburgh is load dominated by the heating season, so most of the energy loss through the envelope would be due to natural gas heating inefficiency. It is also assumed that the hot water heater is powered by electricity.

The average home was assumed to be 1,800 square feet, consisting of two stories.[76] Table 8.9 shows the assumptions used in the model.

Using the total cost of weatherization per household, the energy saving and emission savings were calculated. Sealing air spaces around windows and doors can reduce heating energy consumption by about 10%[77]. ClimateCulture.com was used to determine the emissions savings

[75] http://apps1.eere.energy.gov/weatherization/

[76] http://www.census.gov/hhes/www/housing/ahs/ahs07/tab2-3.pdf

[77] http://apps1.eere.energy.gov/weatherization/

of insulating the attic floor, water heater, and hot water pipes. Using this information, the total tons of eCO2 reduced per year and the annualized cost of the reductions were calculated and can be seen in Table 8.12. It is clear that each reduction actually saves money over time, assuming a 10 year lifetime of the weatherization strategies. When all of the reductions are implemented, about 1.35 tons of eCO2 can be saved in one household, which would result in about $57 of annualized savings. If these weatherization strategies were applied to all of the 132,000 occupied households in Pittsburgh, the cost would be about $75 million, but annual emissions savings would be nearly 180,000 tons eCO2.

Table 8.9. Assumptions of Average Household Characteristics

Household Size (sqft)	1,800
Number of Stories	2
Average footprint (sqft)	900
Average insulation area in attic floor (sqft)	675
Number of Windows	15
Perimeter of 1 Window (ft)	15
Number of Exterior Doors	2
Number of Water Heaters	1
Length of Hot Water Pipes (ft)	50

Table 8.10. House Weatherization Techniques

Weatherization Technique	Energy saved (unit/yr/hh)	unit	eCO2 Reduced (tons eCO2/yr)	Annualized Cost per ton Reduced ($/ton eCO2)
Attic Floor Insulation	4.3	MCF	0.45	-$16
Weather-stripping Windows	2.5	MCF	0.26	-$24
Caulking Windows	2.5	MCF	0.26	-$101
Weather-stripping Doors	2.5	MCF	0.26	-$107
Insulating Hot Water Heater	89	kWh	0.08	-$77
Insulating Hot Water Pipes	38.2	kWh	0.03	-$66
Total			1.35	-$57

Table 8.11 shows the energy and emissions reduction potential of the individual house weatherization techniques, and Table 8.12 shows a summary of implementation impacts on a per household basis.

Table 8.11. Cost, Emissions, and Energy Savings

Weatherization Technique	**Energy saved (unit/yr)**	**unit**	eCO2 **Reduced (tons** eCO2/**yr)**	**Annualized Cost per ton Reduced ($/ton** eCO2)
Attic Floor Insulation	4.3	MCF	0.45	-$109
Weather-stripping Windows	2.5	MCF	0.26	-$108
Caulking Windows	2.5	MCF	0.26	-$107
Weather-stripping Doors	2.5	MCF	0.26	-$108
Insulating Hot Water Heater	88.8	kWh	0.08	-$77
Insulating Hot Water Pipes	38.2	kWh	0.03	-$126
Total			1.35	-$57

Table 8.12. House Weatherization Summary

Capital Cost	$570	Per household
Life Span	10	years
Discount Rate	4%	
Electricity Savings per Year	127	kWh/yr
Natural Gas Savings per Year	11.8	MCF/yr
Energy Savings Cost	-$49	Per year per household
Annualized Cost	-$77	Per year per household
eCO2 Savings	1.35	Tons/year per household
Annualized $/ton eCO2 reduced	-$57	$/ton

8.6. Energy Efficient Residential Appliances

The energy efficient appliances considered as a mitigation option include dishwashers, clothes washers, and refrigerators. The monetary, energy, and emissions savings were calculated using Energy Star's online savings calculator tool[78]. Typically, an Energy Star appliance is a few hundred dollars more expensive. The annual savings range from $25 to $50 and are manly a result or reduced electricity requirements. The capital cost of this mitigation option could be borne by the city in the form of rebates for Energy Star appliances. The annual savings would benefit the consumer. The analysis shows that energy efficient residential appliances are an expensive carbon mitigation option. The cost effectiveness ranges from $500 to $1,000 per ton of carbon reduced.

Assumptions

Besides the appliance specific assumptions made by Energy Star the following assumptions applied to all appliances and were manually corrected in the savings calculator.

[78] www.energystar.gov

Table 8.13. Assumptions of Energy Efficient Residential Appliances

Carbon Intensity of Electricity (lb eCO2/kWh)	1.7
Carbon Intensity of Natural Gas ($/Mcf)	11.38
Residential Cost of Natural Gas (lb eCO2/cf)	0.12
Residential Cost of Electricity ($/kWh)	0.1
Ratio of Appliance per Household	1:1

Using these assumptions in combination with the Energy Star savings calculator the following information can be determined.

Table 8.14. Cost Effectiveness of Energy Star Appliances

Appliance Type	Capital Cost	Annualized Cost ($ 2009)	Annual ton eCO2 reduced/unit	Annualized $ / ton eCO2 reduced
Clothes Washer	$500	11	0.02	508
Dishwasher	$545	36	0.07	553
Refrigerator	$1,100	64	0.06	1,056

The annualized cost was calculated by subtracting the annual savings over the lifetime of the appliance from the capital cost of the appliance and then determining the equivalent annuity of the difference over the lifetime of the appliance for discount rate of 4%. The tons of eCO2 reduced per unit are specified in the savings calculator. Finally, the cost effectiveness is simple the annualized cost divided by the tons of carbon reduced.

The scalability of the mitigation option was estimated by assuming that there is on average one appliance of each type per household. Given that the city of Pittsburgh has approximately 132,000 households, each appliance can be implemented 132,000 times.

8.7. Residential Water Conservation

Water conservation energy reductions were estimated for four fixtures and two appliances: a showerhead, a bath faucet, a kitchen faucet, a toilet, a dishwasher, and a clothes washer.

Four sources of energy reductions were estimated for residential water conservation technologies:

1) Reductions in the energy required to treat drinking water;
2) Reductions in the energy required to distribute (pump) drinking water;
3) Reductions in natural gas consumptions for water heating;
4) Reductions in the energy required to treat wastewater treatment.

For each of the above activities, the energy required per unit volume of water was estimated. Energy requirements for drinking water distribution (item 2 above) and water heating (item 3 above) were derived from fundamentals. Water and wastewater treatment energy requirements were taken from the literature. The unit energy requirements to deliver, heat, and dispose of household drinking water are summarized in Table 8.15.

Table 8.15. Energy Requirements for Household Drinking Water

Natural Gas Use	Value	Units	Reference
Hot water use	1	gal	
Tap Water Temp	10	deg C	
Tap Water Temp	50	deg F	
Target Hot Water Temp	55	deg C	
Target Hot Water Temp	131	deg F	
Specific heat of water	4186	joule/kg deg C	
Specific heat water	0.0044	kwh/gal deg C	
Losses	0.1	as fraction of total use	Assume
Heating Energy Required	0.22	kwh/gal	
Heating Energy Required	744	BTU/gal	
Natural Gas Required	***0.72***	***cf/gal***	
Water Distribution			
Assumed Pumping Head	300	ft	
Water Energy	0.94	kWh/1,000 gal	
Pump Efficiency	0.75	fraction	
Pump/Electrical Energy	1.26	kWh/1,000 gal	
Literature Estimate	0.9	kWh/1,000 gal	Bunn 2006 [79]
Final Estimate	***1.0***	***kWh/1,000 gal***	
Water Treatment	***1.8***	***kWh/1,000 gal***	Tarantini & Ferri 2001 [80]
Wastewater treatment	1.2-2.5	kWh/1,000 gal	Tchobanoglous et al 2001[81]
	0.76-1.9	kWh/1,000 gal	Sahely et al 2006 [82]
	0.70-2.45	kWh/1,000 gal	Lundin 1999 [83]
Final Estimate	***1.5***	***kWh/1,000 gal***	

The energy reductions from water saving devices were then calculated as the marginal water savings associated with the device multiplied by the unit energy use associated with each of the above four activities, as summarized in the equation below:

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[79] Bunn S (2006) "Pump Scheduling Optimization in Four US Cities: Case Studies" Water Distribution Systems Analysis Symposium 2006- Proceedings of the 8th Annual Water Distribution Systems Analysis Symposium; Cincinnati, OH. American Society of Civil Engineers

[80] Assume slightly higher than WWTP based upon Tarantini M, Ferri F (2001) "LCA of drinking and wastewater treatment systems of Bologna city: Final results" Proceedings of the 4th Inter-Regional Conference on Environment and Water. P 27–31

[81] Wastewater engineering: treatment and reuse (2003) "Tchobanoglous, G; Burton, FL; Stensel, HD. McGraw-Hill. pp. 1704

[82] Interpreted with assumptions from Sahely, H. R.; Maclean, H. L.; Monteith, H. D.; Bagley, D. M. (2006) Comparison of On-Site and Upstream Greenhouse Gas Emissions from Canadian Municipal Wastewater Treatment Facilities. J. Environ. Eng. Sci. 5(5): 405–415

[83] Lundin M (1999) "Assessment of the environmental sustainability of urban water systems" Technical Environmental Planning, Chalmers University of Technology p 39

$$Energy\ Reduced_{Device} = (Q_{Exis\ Device} - Q_{Efficient\ Device}) \times (Annual\ Use) \times (E_{Water\ Treatment} + E_{Water\ Distribution} + E_{Wastewater\ Treatment})$$
$$+ (Q_{Exis\ Device} - Q_{Efficient\ Device}) \times (Annual\ Use) \times (Fraction\ Hot\ Water) \times (E_{Natural\ Gas})$$

Where
- Q is a flow in volume per time
- $Q_{Exis\ Device} - Q_{Efficient\ Device}$ is the marginal water savings
- Annual use is a volume
- E is in energy required per volume

Total water, energy, and greenhouse gas reduction estimates from residential water saving devices are summarized in the table below. The capital cost of each fixture was estimated from scanning on-line sales. The capital cost of each appliance was estimated using product summaries at www.greenerchoices.org.

Water use associated with existing and efficient appliances were taken product specifications and the following additional sources:

1) Showerhead
   a. http://www.fypower.org/res/tools/products_results.html?id=100160
   b. http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13050
2) Bath Faucet
   a. http://www.epa.gov/WaterSense/specs/faucet_final.htm
   b. http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13050
3) Kitchen Faucet
   a. http://www.fypower.org/res/tools/products_results.html?id=100160
4) Toilet
   a. http://www.epa.gov/WaterSense/specs/het_spec.htm
5) Dishwasher
   a. http://www.greenerchoices.org/ratings.cfm?product=dishwasher
   b. http://srpnet.apogee.net/homesuite/library/watercons/?utilid=srpnet&id=3277
   c. http://msucares.com/pubs/publications/p2271.html
6) Clothes Washer
   a. http://www.aceee.org/consumerguide/laundry.htm
   b. http://www.greenerchoices.org/ratings.cfm?product=washer

Table 8.16: Summary of Water, Energy, and Greenhouse Gas Reduction Estimates

Fixture	Flow Units	Efficient fixture flow	Existing fixture flow	Marginal Water Savings	Portion hot water	Daily use units	Daily use
Showerhead	gpm	1.5	3	1.5	0.7	minutes	20
Bath Faucet	gpm	1.2	2.2	1	0.2	minutes	10
Kitchen Faucet	gpm	2	4	2	0.3	minutes	15
Toilet	gal/flush	1.28	1.6	0.32	0	flushes	10
Dishwasher	gal/cycle	5	14	9	1	cycles	0.75
Clothes Washer	gal/load	25	40	15	0.5	loads	0.33

Fixture	Capital Cost	Annual Water Savings (gal)	Annual Hot water savings (gal)	Water Heater Nat Gas Saved (Mcf)	Water Treatment Elec Saved (kWh)	Wastewater Treatment Elec Saved (kWh)	Water Distribution Elec Saved (kWh)
Showerhead	$30	10,950	7,665	5.54	19.7	16.4	11.0
Bath Faucet	$10	3,650	730	0.53	6.6	5.5	3.7
Kitchen Faucet	$10	10,950	3,285	2.38	19.7	16.4	11.0
Toilet	$350	1,168	0	0.00	2.1	1.8	1.2
Dishwasher	$1,000	2,464	2,464	1.78	4.4	3.7	2.5
Clothes Washer	$1,000	1,807	903	0.65	3.3	2.7	1.8

Fixture	Annual Water Cost Savings ($)	Annual Nat Gas Savings ($)	Annual Elec Savings ($)	Total Annual Savings ($)	Lifetime (yrs)	Annualized Cost ($)	Private Annualized Cost
Showerhead	($77)	($63)	($5)	($144)	20	($142)	($137)
Bath Faucet	($26)	($6)	($2)	($33)	20	($32)	($31)
Kitchen Faucet	($77)	($27)	($5)	($108)	20	($108)	($103)
Toilet	($8)	$0	($1)	($9)	20	$17	$18
Dishwasher	($17)	($20)	($1)	($39)	10	$85	$86
Clothes Washer	($13)	($7)	($1)	($21)	10	$102	$103

Fixture	Municipal Annualized Cost	Total eCO2 Mitigated (tons)	Private Total eCO2 Mitigated (tons)	Municipal Total eCO2 Mitigated (tons)	Annualized $ / ton eCO2 reduced	Private Annualized $ / ton eCO2 reduced	Municipal Annualized $ / ton eCO2 reduced
Showerhead	($5)	0.37	0.33	0.04	($381)	($413)	($118)
Bath Faucet	($2)	0.05	0.03	0.01	($719)	($972)	($118)
Kitchen Faucet	($5)	0.18	0.14	0.04	($589)	($721)	($118)
Toilet	($1)	0.004	0.00	0.00	$4,003	0	($118)
Dishwasher	($1)	0.12	0.11	0.01	$731	$802	($118)
Clothes Washer	($1)	0.05	0.04	0.01	$2,236	$2,633	($118)

8.8. Renewable Energy Solutions

Renewable energy is a large scale solution to reduce emissions associated with energy consumption. Fossil fuel based power plants are the primary energy sources of the United States,. Finding a solution to target one of the primary sources of emissions holds significant potential to reduce the carbon footprint of a community. Two common renewable energy solutions that are utility-scale are wind energy and solar thermal.

Recommendation 1: Building Wind Energy

Wind energy has been a developing industry that is projected to continue growth for the foreseeable future, as much of the US has the environmental conditions to take advantage of this technology. This analysis will look at the costs associated with wind turbines and their effectiveness in reducing greenhouse gases compared to a coal power plant.

The scope of the cost of wind energy is difficult to define, but this analysis will focus on the levelised cost of energy for wind turbines. As of 2007, wind energy is estimated to be $1,920 per kilowatt[84]. This cost includes installation of the wind system and is scaled by the capacity factor. Converting this to megawatt-hours, it is expected to cost approximately $220 per megawatt-hour. A 4% discount rate is assumed in these calculations. The life span of a wind turbine is expected to be 20 years.[85]

In terms of greenhouse gas reductions, the use phase of wind energy has essentially zero emissions, while the average coal power plant in the US emits 0.96 tons eCO2 per megawatt-hour[86].

Table 8.17. Wind Energy Summary

Levelised Cost of Electricity	220	$/MWh
Life span	20	years
Discount rate	4%	
Annualized costs	16	$/MWh
eCO2 savings	0.96	Tons/MWh
Cost/ton eCO2 reductions	229	$/ton

Recommendation 2: Building Concentrating Solar Power

Concentrating solar thermal technology is also a widely used solution to provide bulk electricity from a renewable source. Building solar thermal plants are on the costly side before subsidies are considered. The expected life of a solar thermal plant is approximately 25 years.[87]

To calculate the costs associated with solar thermal power plants, an existing project is referenced, the Nevada Solar One. Its cost was $266 million for a 64 megawatt plant, which outputs 130 million kilowatt-hours.[88] This price also is the levelised cost of energy, which factors in a 24% capacity factor. This converts into approximately $2000 per megawatt-hour.

The operation of a solar thermal power plant does not emit greenhouse gases, so when compared to a coal power plant, it is a full reduction of emissions of 0.96 tons per megawatt hour.

[84] http://www1.eere.energy.gov/windandhydro/pdfs/43025.pdf
[85] http://www.getransportation.com/na/en/wind.html
[86] http://www.eia.doe.gov/fuelelectric.html
[87] http://www.solarpaces.org/Library/docs/STPP%20Final%20Report2.pdf
[88] http://www.c40cities.org/bestpractices/renewables/nevada_solar.jsp

Table 8.18. Solar Power Summary

Levelised Cost of Electricity	2000	$/MWh
Life span	25	years
Discount rate	4%	
Annualized costs	128	$/MWh
eCO2 savings	0.96	Tons/MWh
Cost/ton eCO2 reductions	2100	$/ton

Recommendation 3: Purchasing Renewable Energy

Another approach to benefitting from renewable energy is to purchase electricity from existing power plants that use a renewable source. One way to monitor the amount of renewable energy purchased is through renewable energy certificates. These certificates serve as documentation that 1 megawatt-hour of electricity was generated from an eligible renewable energy source.

In terms of purchasing cost, electricity from renewable energy sources adds an average premium of 2₵ per kilowatt-hour, with a range of 0.4₵ to 5.6₵.[89] Scaling up to a megawatt-hour, the cost is approximately $20 per megawatt-hour. Thus, the cost per ton of greenhouse gas reduced is $21.

Table 8.19. Purchasing Rewables Summary

Levelised Cost of Electricity	20	$/MWh
eCO2 savings	0.96	Tons/MWh
Cost/ton eCO2 reductions	21	$/ton

Cost Implications for Pittsburgh

Although it is may not be practical to shift all of Pittsburgh's electricity consumption to renewable energy, an estimate is made for comparison purposes. Pittsburgh's electricity consumption is estimated to be 4.2 million megawatt-hours in 2003.[90]

Table 8.20. Summary of Alternative Energy Sources

Source	**$ / MWh**	**Overall Cost**
Build Wind Energy	220	$924 million
Build Concentrating Solar Power	2000	$8.4 billion
Purchase Electricity from Renewable Sources	20	$84 million

8.9. Vending Misers

Vending misers are devices that can be installed on vending machines to drastically improve their energy efficiency, typically doubling it[91]. Vending misers are a motion sensor that shut off

[89] http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=1
[90] http://www.pittsburghclimate.org/documents/PittsburghInventoryReport.pdf
[91] Tufts Climate Initiative. (2008). "Vending Misers: Facts and Issues." http://www.tufts.edu/tie/tci/pdf/VendingMiserHandout.pdf. 14 April 2009.

the lights in a vending machine when no one is in the room. Installing them on all vending machines in the city of Pittsburgh could result in energy and cost savings and a positive cost-effectiveness ratio.

USA Technologies makes these misers and they quote a cold drink machine vending miser at $179 and a snack machine vending miser at $79. They also reasonably assume that the power used for a cold drink machine is 400 W and 80 W for a snack vending machine. The website assumes that there are 54% energy savings for cool drink machines and 45% energy savings for snack machines, which was then used to determine the energy in kWh/year and cost in $/year saved for each vending miser. Other assumptions made are that all vending machines run 365 days/year, 24 hours/day. The assumed discount rate is 4%, the cost for electricity is $.10, and the lifetime of a vending miser is 10 years[92].

Table 8.21. Vending Miser Summary

	Cold Drink	Snack
Cost/Miser	$179	$79
Power (W)	400	80
Hours/Year	8760	8760
kWhSaved/Year	1612	385
Tons CO_2 Saved/Year	1.37	0.33
Annualized Savings/Year	$139	$29
Net Benefit ($/ton CO_2Reduced)	$102	$88

Max constraint:

Previous estimate made by group states that there is approximately 180,000,000 sq ft of commercial space in the city. The city council building has 10 vending machines and 260,000 sq ft. Assuming 10 machines/260,000 sq ft = .0000385 machines/sq ft. This estimates out to be about 7000 machines in the city. It's also assumed that 3000 are snack and 4000 are cold drink.

8.10. Biking and Ride Sharing

The benefit to increased biking and ride sharing is reduced vehicle miles traveled (VMT). Below are the cost benefits of alternative transportation to the individual. However, the costs most valuable to the municipal government are the costs of promoting biking and ridesharing. There are multiple methods for supporting alternative transportation such as advertising, installing or widening bike lanes, installing bike rakes, issuing more biking awareness road signs, and creating ridesharing programs. The benefits of reduced VMT are shown below, but how that will be accomplished is the bigger and undefined issue.

The Internal Revenue Service (IRS) issues annually a standard mileage rate which approximates the costs of operating a vehicle per mile driven. This number takes into account the initial cost of

[92] Energy Management: VendingMiser." USA Technologies. 14 Apr. 2009 <http://www.usatech.com/energy_management/energy_vm.php>

the car, insurance, maintenance, depreciation and fuel consumption. For 2009, the standard mileage rate for a car is 55 cents/mile[93]. Over 50% of this cost is variable by the miles driven[94]. By a conservative approximation, 28 cents/mile is for gasoline cost and depreciation. Therefore, 27 cents/mile is spent for having a car but not driving it.

Table 8.22. Assumed Car Ownership and Operating Costs

	Annualized Cost (cents per mile)
Owning and driving a car	55
Owning but not driving a car	27
Operating a car	28

8.11. **Biking**

In order to find the cost of biking to work, the owning and operating cost of a bike must be defined. The cost of owning and operating a bike is between $200[95] and $400[96] a year. Assuming that bike commuting to work is for 250 days/year and approximately 8 miles each way, the cost per passenger mile for biking is 8 cents/mile. Therefore, the cost of bike commuting is the cost of a bike plus the cost of having a car but not driving it, which is 35 cents/mile. Also, one mile avoided driving is equivalent to one pound of eCO2 mitigated[97]. The cost effectiveness is calculated as the ratio of the annualized costs to the eCO2 savings and is approximately $700/ton reduced.

Table 8.23. Summary of Biking to Work

	Annualized Cost (cents per mile)	Cost per ton reduced
Owning but not driving a car	27	
Owning a bike	8	
Biking to work	35	$700

One way to promote biking is to install more bike lanes. Since 40% of all trips taken in the United States are within a distance of two miles, biking should be encouraged for more than work commuting[98]. The maximum increase in bike commuting by implementing a bike plan was found by doubling the percentage of biking done currently in Pittsburgh. All of the data was provided by the US Bureau of the Census. Pittsburgh is not in the top five cities for cycling where the range of biking to work is between two and four percent, so less than 2% of workers bike to work[99]. The assumption is that the best plans implemented will only mean 2% more

[93] Internal Revenue Service, 2009. http://www.irs.gov/newsroom/article/0,,id=200505,00.html

[94] "Your Driving Costs 2006". http://www.viainfo.net/FaresAndPasses/YourDrivingCosts2006.pdf

[95] *Cutting Your Car Use*. http://books.google.com/books?hl=en&lr=&id=4dl0c4vIu-gC&oi=fnd&pg=PA1&dq=money+saved+carpooling&ots=Iy9BVx2QXY&sig=5s2JLpWqWOWzIAgQkQR1wqYF5dU#PPA5,M1

[96] Transportation Alternatives. http://bike-pgh.org/2009/03/18/cost-of-owning-a-car-about-2250-per-day/

[97] Climatecrisis.net, 2006: "Reduce Your Impact at Home." http://www.climatecrisis.net/takeaction/whatyoucando/

[98] Nationwide Personal Transportation Survey. http://www.bikeleague.org/resources/why/environment.php

[99] "City Commuting", 2008. http://www.sustainlane.com/us-city-rankings/categories/city-commuting

biking in the city since the top cities do not have more than 4% bike transportation. From the census tract data for VMT by the National Household Travel Survey, it is assumed that the VMT for work trips is about 800,000 miles annually. Therefore, the 80% driving is reduced to 78% driving which translates to 20,000 miles avoided. For every mile, one pound of eCO2 is mitigated. Doubling the biking population means 20 tons of eCO2 reduced each year. Since 16% of Pittsburgh's carbon footprint is due to gasoline emissions, this reduction is 0.002% of the community transportation related emissions for Pittsburgh in 2003[100].

8.12. **Ride Sharing**

For ridesharing, the passengers in the shared vehicle are sharing the costs of the variable cost, the 28 cents/mile for gasoline and depreciation. Each passenger is still paying for owning but not driving in addition to the reduced cost of driving. Ride sharing between two people would be 41 cents/mile. The cost effectiveness is calculated as the ratio of the annualized costs to the eCO2 savings and is approximately $820/ton reduced.

Table 8.24. Summary of Ride Sharing

	Annualized Cost (cents per mile)	Cost per ton reduced
Owning but not driving a car	27	
Operating a car	28	
Ride sharing with n passengers	27 + 28/n	
Ride sharing between 2 people	41	$820

The maximum increase in ride sharing by a city action was reasonably estimated by doubling the percentage of ride sharing done currently in Pittsburgh. All of the data was provided by the US Bureau of the Census. In Pittsburgh for 2007, 80% workers drove to work and only 9% of workers carpool[101]. Doubling the number of workers that ride share (5% more workers not driving to work) translates to 50,000 miles avoided. For every mile, one pound of eCO2 is mitigated. Doubling the biking population means 50 tons of eCO2 reduced each year. Since 16% of Pittsburgh's carbon footprint is due to gasoline emissions, this reduction is 0.005% of the community transportation related emissions for Pittsburgh in 2003[8].

Table 8.25. Potential Impacts of Biking and Ride Sharing

	Current % participation	Maximum % Increase	VMT % avoided	VMT reduced
Biking to work	2%	2%	2.50%	20000 miles
Ride sharing	9%	10%	6.25%	50000 miles

[100] Pittsburgh GHG Inventory, 2003. http://www.pittsburghclimate.org/documents/PittsburghInventoryReport.pdf

[101] "Facts for Features". US Census Bureau. http://www.census.gov/Press-Release/www/releases/archives/facts_for_features_special_editions/013157.html

8.13. **Commercial Compact Fluorescent Lights (CFLs)**

Lighting is the second most energy intensive commercial building activity after space heating, accounting for roughly 20% of total energy use[102]. Many large commercial offices have begun to replace the standard incandescent lights with CFLs to reduce energy consumption. However, many smaller retail and service businesses are still using less efficient lighting because of its lower upfront cost. The City of Pittsburgh plans to partake in the EPA Energy Star Program, "Change a Light Day," which involves the distribution of free CFLs and information material in efforts to help encourage the use of more efficient lighting technology.

A 60 watt incandescent bulb is equivalent to a 15 watt CFL which has an expected lifetime of 10,000 hours or approximately five years, whereas the standard incandescent bulb only lasts 750 hours or five months. The initial cost of an incandescent bulb is about $.50, while a CFL bulb can be purchased for approximately $3.50[103]. Assuming that commercial lighting is only on during business hours (5 days a week and 8 hours per day), a standard incandescent bulb consumes roughly 125 kWh per year, while a CFL uses about 30 kWh per year. This difference in energy use results in a 95 kWh savings which is equivalent to the reduction of approximately .08 tons of eCO2 annually per CFL bulb.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, a CFL bulb will result in roughly $9 of energy savings per year. Maintenance savings would also be observed since a CFL bulb would only need to be replaced every five years instead of every five months. However, due to variability in maintenance costs, these savings were not estimated. Using a five year lifecycle, approximately .4 tons of eCO2 are mitigated per CFL bulb. The annualized cost effectiveness was determined to be -$9 per ton eCO2, and the results of utilizing a CFL light bulb in a commercial building are summarized below.

Table 8.26. Summary of Compact Fluorescent Lights

Capital Cost	$3.50	Per CFL
Life span	5	years
Discount rate	4%	
Energy Savings per year	95	kWh/year
Energy savings cost	$9	Per year per CFL
Annualized costs	-$9	Per year per CFL
eCO2 savings	.08	Tons/year per CFL
Annualized $/ton eCO2 reduced	-$108	$/ton

[102] Energy Kid's Page: Commercial Energy Use. Energy Information Administration. http://www.eia.doe.gov/kids/energyfacts/uses/commercial.html

[103] Compact Fluorescent Light Bulbs – Savings Calculator. U.S. Environmental Protection Agency - Energy Star. http://www.energystar.gov/index.cfm?c=cfls.pr_cfls

8.14. Energy Star® Office Equipment

Energy Star® is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy that is designed to help recognize a variety of energy efficient products[104]. Many businesses are beginning to replace office equipment with more efficient Energy Star® labeled models. Energy use from office equipment only accounts for approximately 3% of the total for commercial buildings[105]. This coupled with high capital costs contribute to the poor cost effectiveness for many of these energy efficient products.

Several of the mitigation alternatives in the Pittsburgh Climate Action Plan call for the increased use of Energy Star® products. The following analysis reports the estimated eCO2 mitigation potential and cost effectiveness for a variety of Energy Star® qualified office equipment.

Copiers

A conventional and an Energy Star® qualified copier (having capabilities of producing more than 50 images per minute) are both assumed to have a lifetime of six years and an initial cost of $15,000[106]. Assuming that a commercial copier is left on all year, a conventional unit consumes roughly 848 kWh per year, while an Energy Star® qualified unit uses about 790 kWh per year. This difference in energy use results in a 58 kWh savings which is equivalent to the reduction of approximately .05 tons of eCO2 annually per Energy Star® copier.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® copier will only result in roughly $6 of energy savings per year. Since a conventional copier has the same lifetime as an Energy Star® copier, no maintenance savings are expected. Using a six year lifecycle a total of approximately .3 tons of eCO2 are mitigated per Energy Star® copier. The annualized cost effectiveness was determined to be $59,000 per ton eCO2, which indicates that costs are incurred when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified copier in commercial buildings are summarized below in Table 8.27.

Table 8.27. Commercial Energy Star® Copier Summary

Capital Cost	$15,000	Per copier
Life span	6	years
Discount rate	4%	
Energy Savings per year	58	kWh/year
Energy savings cost	$9	Per year per copier
Annualized costs	$2,900	Per year per copier
eCO2 savings	.05	Tons/year per copier
Annualized $/ton eCO2 reduced	$59,000	$/ton

104 History of Energy Star®. U.S. Environmental Protection Agency. http://www.energystar.gov/index.cfm?c=about.ab_history

105 Energy Kid's Page: Commercial Energy Use. Energy Information Administration. http://www.eia.doe.gov/kids/energyfacts/uses/commercial.html

106 Copiers and Fax Machines – Copier Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CX

Printers

A conventional and an Energy Star® laser printer are both assumed to have a lifetime of five years and an initial cost of $950 (price differences were not noticed between conventional and Energy Star® scanners with similar capabilities and features). Assuming that a commercial printer is left on all year, a conventional unit consumes roughly 551 kWh per year, while an Energy Star® qualified unit uses about 406 kWh per year[107]. This difference in energy use results in a 145 kWh savings which is equivalent to the reduction of approximately .12 tons of eCO2 annually per Energy Star® laser printer.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® laser printer will only result in roughly $15 of energy savings per year. Since a conventional copier has the same lifetime as an Energy Star® laser printer there are assumed to be no maintenance savings. Using a five year lifecycle a total of approximately .6 tons of eCO2 are mitigated per Energy Star® laser printer. The annualized cost effectiveness was determined to be $1,600 per ton eCO2, which indicates that costs are incurred when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified printer in commercial buildings are summarized below in Table 8.28.

Table 8.28. Commercial Energy Star® Laser Printer Summary

Capital Cost	$950	Per printer
Life span	5	years
Discount rate	4%	
Energy Savings per year	145	kWh/year
Energy savings cost	$15	Per year per printer
Annualized costs	$199	Per year per printer
eCO2 savings	.12	Tons/year per printer
Annualized $/ton eCO2 reduced	$1,600	$/ton

Scanners

A conventional and an Energy Star® scanner are both assumed to have a lifetime of four years and an initial cost of $140 (price differences were not noticed between conventional and Energy Star® scanners with similar capabilities and features). Assuming that a commercial printer is left on all year, a conventional unit consumes roughly 51 kWh per year, while an Energy Star® qualified unit uses about 35 kWh per year[108]. This difference in energy use results in a 16 kWh savings which is equivalent to the reduction of approximately .01 tons of eCO2 annually per Energy Star® scanner.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® qualified scanner

[107] Printers, Scanners and All-in-one Devices – Printer Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=PS
[108] Printers, Scanners and All-in-one Devices – Scanner Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=PS

will only result in roughly $2 of energy savings per year. Since a conventional scanner has the same lifetime as an Energy Star® scanner there are assumed to be no maintenance savings. Using a four year lifecycle, a total of approximately .04 tons of eCO2 are mitigated per Energy Star® scanner. The annualized cost effectiveness was determined to be $2,700 per ton eCO2, which indicates that costs are incurred when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified scanner in commercial buildings are summarized below in Table 8.29.

Table 8.29. Commercial Energy Star ® Scanner Summary

Capital Cost	$140	Per scanner
Life span	4	years
Discount rate	4%	
Energy Savings per year	16	kWh/year
Energy savings cost	$2	Per year per scanner
Annualized costs	$37	Per year per scanner
eCO2 savings	.01	Tons/year per scanner
Annualized $/ton eCO2 reduced	$2,700	$/ton

Computers

A conventional and an Energy Star® qualified computer are both assumed to have a lifetime of four years and an initial cost of $900 (price differences were not noticed between conventional and Energy Star® computers with similar capabilities and features) [109]. Assuming that both computer types are only turned off at night 36% of the time, and that a conventional unit does not have sleep setting activated while the Energy Star® computer does; a conventional unit consumes roughly 540 kWh per year, while an Energy Star® qualified unit uses about 85 kWh per year[110]. This difference in energy use results in a 455 kWh savings which is equivalent to the reduction of approximately .4 tons of eCO2 annually per Energy Star® computer.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® qualified computer will result in roughly $45 of energy savings per year. Since a conventional scanner has the same lifetime as an Energy Star® computer there are assumed to be no maintenance savings. Using a four year lifecycle, a total of approximately 1.6 tons of eCO2 are mitigated per Energy Star® computer. The annualized cost effectiveness was determined to be $520 per ton eCO2, which indicates that costs are incurred when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified computer in commercial buildings are summarized below in Table 8.30.

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[109] Computers– Computers Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CO

[110] After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment. Ernest Orlando Lawrence Berkeley National Laboratory. http://www.osti.gov/bridge/servlets/purl/821675-waYRd0/native/821675.pdf

Table 8.30. Commercial Energy Star Computer Summary

Capital Cost	$900	Per computer
Life span	4	years
Discount rate	4%	
Energy Savings per year	455	kWh/year
Energy savings cost	$45	Per year per computer
Annualized costs	$202	Per year per computer
eCO2 savings	.4	Tons/year per computer
Annualized $/ton eCO2 reduced	$520	$/ton

Monitors

A conventional is assumed to have an initial cost of $150 and for an Energy Star® qualified monitor the initial cost is assumed to be $300. Both monitor types are assumed to have a lifetime of four years[111]. Assuming that both are only turned off at night 36% of the time, and that a conventional unit does not have sleep setting activated while the Energy Star® monitor does; a conventional unit consumes roughly 460 kWh per year, while an Energy Star® qualified unit uses about 35 kWh per year[112]. This difference in energy use results in a 425 kWh savings which is equivalent to the reduction of approximately .36 tons of eCO2 annually per Energy Star® monitor.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® qualified monitor will result in roughly $43 of energy savings per year. Since a conventional scanner has the same lifetime as an Energy Star® monitor there are assumed to be no maintenance savings. Using a four year lifecycle, a total of approximately 1.4 tons of eCO2 are mitigated per Energy Star® monitor. The annualized cost effectiveness was determined to be $110 per ton eCO2, which indicates that costs are incurred when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified monitor in commercial buildings are summarized below in Table 8.31.

Table 8.31. Commercial Energy Star Monitor Summary

Capital Cost	$300	Per monitor
Life span	4	years
Discount rate	4%	
Energy Savings per year	425	kWh/year
Energy savings cost	$43	Per year per monitor
Annualized costs	$40	Per year per monitor
eCO2 savings	.36	Tons/year per monitor
Annualized $/ton eCO2 reduced	$110	$/ton

[111] Monitors/Displays– Monitors Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=MO

[112] After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment. Ernest Orlando Lawrence Berkeley National Laboratory. http://www.osti.gov/bridge/servlets/purl/821675-waYRd0/native/821675.pdf

Hot/Cold Water Cooler

A conventional and an Energy Star® water cooler are both assumed to have a lifetime of ten years and an initial cost of $190 (price differences were not noticed between conventional and Energy Star® water coolers with similar hot and cold water capabilities). Assuming that a commercial water cooler is left on all year, a conventional unit consumes roughly 800 kWh per year, while an Energy Star® qualified unit uses about 440 kWh per year[113]. This difference in energy use results in a 360 kWh savings which is equivalent to the reduction of approximately .3 tons of eCO2 annually per Energy Star® water cooler.

In order to determine the annualized cost, as well as the total emissions saved, a 4% interest rate was assumed. Using an electricity cost of $0.10 per kWh, an Energy Star® qualified water cooler will result in roughly $36 of energy savings per year. Since a conventional scanner has the same lifetime as an Energy Star® water cooler there are assumed to be no maintenance savings. Using a ten year lifecycle, a total of approximately 3 tons of eCO2 are mitigated per Energy Star® water cooler. The annualized cost effectiveness was determined to be -$40 per ton eCO2, which indicates that savings are acquired when using this alternative to mitigate carbon. All of the results of utilizing an Energy Star® qualified water cooler in commercial buildings are summarized below in Table 8.32.

Table 8.32. Commercial Energy Star Hot/Cold Water Cooler Summary

Capital Cost	$190	Per water cooler
Life span	10	years
Discount rate	4%	
Energy Savings per year	360	kWh/year
Energy savings cost	$36	Per year per water cooler
Annualized costs	$13	Per year per water cooler
eCO2 savings	.3	Tons/year per water cooler
Annualized $/ton eCO2 reduced	-$40	$/ton

8.15. Urban Forestry

Urban forestry was one of the unique actions looked at for Pittsburgh's CAP. In the CAP, the action is listed as having an unknown GHG reduction. There is also not a specific number of trees to be planted. While these uncertainties exist with Pittsburgh's CAP, there are a number of other resources that give information about urban forestry.

In order to calculate the emissions reductions associated with urban forestry as a whole, the first step was to calculate the emissions reductions in terms of a single tree. Unlike many actions that reduce emissions by reducing use or production of something, trees reduce emissions by sequestering carbon. In this way, they are not actually reducing energy use or emissions released, but they are collecting a portion of the emissions. Calculating the emissions reduction on a per tree basis will give an idea of their effectiveness at this process. Case studies from the

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[113] Water Coolers – Water Coolers Savings Calculator. Energy Star. http://www.energystar.gov/index.cfm?c=water_coolers.pr_water_coolers

California Climate Action Team, Million Trees LA, Trees Forever, TreeLink[114], and the Colorado Tree Coalition[115] were used to calculate this number. These case studies are of actual results from urban forestry in various cities across the country. There were a fairly wide range of results, leading to an average reduction value of 0.19 tons of eCO2 reduced per tree per year. The results can be seen below in Table 8.33.

Table 8.33. Case Studies of Emissions Reductions from Urban Forestry

Case Study	Emissions Reduction
California Climate Action Team	0.70 MT eCO2/tree/yr
Million Trees LA	0.03 MT eCO2/tree/yr
Trees Forever	0.05 MT eCO2/tree/yr
TreeLink	0.18 MT eCO2/tree/yr
Colorado Tree Coalition	0.01 MT eCO2/tree/yr
AVERAGE	**0.19 MT eCO2/tree/yr**

The costs associated with urban trees were determined similarly by using a number of urban forestry case studies[116]. Both the initial capital cost and yearly operation and maintenance costs were determined for an average urban tree. The initial capital cost includes the price of the tree as well as installation of the tree. While the specific species of tree will differ by geographic area, the tree will generally be similar in type and price. All of the case study values were averaged to get one overall estimate value of the capital cost. The estimate was $58 for one tree. Additionally, a cost for operation and maintenance (O&M) was determined. This cost is associated with the yearly work necessary to keep the tree alive and healthy. This could account for actions like watering, pruning, or general maintenance. These costs were found in a number of case studies[117] and were average to get a yearly O&M cost of $14 per tree. These numbers do assume that there is not just a single tree being installed, but instead a scaled up project that installs a number of trees. The costs would certainly increase with a single tree. Table 8.34 and Table 8.35 show the capital and O&M costs for an urban tree.

Table 8.34. Case Studies of Capital Cost or Urban Tree

Case Study	Capital Cost
Canada Mortgage and Housing Corp.	85 $/tree
Urban Forest Research	50 $/tree
Urban Tree Planting	37.5 $/tree
AVERAGE	**58 $/tree**

All of this data can be combined to find a value for the annualized cost per ton of eCO2 reduced. Factoring in the emissions reduction value and the cost values along with an assumed 50 year lifetime of an urban tree[118], urban forestry as a whole has an annualized cost per ton eCO2

[114] http://www.treelink.org/docs/29_reasons.phtml
[115] http://www.coloradotrees.org/benefits.htm
[116] http://www.cmhc-schl.gc.ca/en/inpr/su/waco/alstmaprrepr/alstmaprrepr_006.cfm
[117] http://www.ci.missoula.mt.us/parksrec/urbanforestry.htm
[118] http://www.canr.uconn.edu/ces/forest/fact1.htm

reduced of $88. The final step is to look at what the maximum constraint for urban forestry is. This task is difficult for this action, since more trees can almost always be planted. In order to get a realistic estimate of the upper-bound on tree numbers, the Million Trees LA[119] and Million Trees NYC[120] projects were consulted. Their number of trees and city land area were used to come up with a similar maximum tree value for Pittsburgh's land area. The data, seen in Table 8.36, was used to create a maximum urban forestry plan of 140,000 trees.

Table 8.35. Case Studies of O&M Cost of Urban Tree

Case Study	O&M Cost	
Missoula Parks and Rec.	11.6	$/tree/year
APWA Reporter	22.5	$/tree/year
Canada Mortgage and Housing Corp.	7.5	$/tree/year
AVERAGE	**14**	**$/tree/year**

Table 8.36. Estimate of Max Trees for Pittsburgh

City	City Land Area		Trees
New York City	305	sqmi	1,000,000
Los Angeles	469	sqmi	1,000,000
AVERAGE	387	sqmi	1,000,000
Pittsburgh	**56**	**sqmi**	**140,000**

This is reasonable considering that the most recent census found Pittsburgh to have approximately 30,000 trees within its city limits. This max constraint would significantly increase this number, but is in the same order of magnitude. The overall data and information above is summarized in Table 8.37.

Table 8.37. Summary Table for Urban Forestry

Capital cost	58	$
Life span	50	years
Discount rate	4	%
Annualized costs	17	$/year
eCO2 savings	0.19	tons/year
Cost/ton eCO2 reductions	88	$/ton

8.16. **Hybrid City Vehicles**

The vehicle fleet of a city is ordinarily not associated with efficient and clean vehicles, which assist in reducing carbon emissions. Pittsburgh's fleet is no different, as it is composed of over 1,000 vehicles without a strong focus on fuel efficiency and carbon footprint. Examining the city fleet needs to be done without compromising the necessary services that these vehicles are a part of. Because of this, the analysis of the city fleet will ignore the fire, police, and EMS service vehicles. It is vital that all of these emergency vehicles be effective and practical.

[119] http://www.milliontreesla.org/mtabout.htm
[120] http://www.milliontreesnyc.org/html/about/about.shtml

Out of the 1,047 vehicles that are in Pittsburgh's city fleet, 453 of these are a part of the police, fire, or EMS department and were not examined in the analysis. Similarly, specialty vehicles (street sweepers, large dump trucks, etc.) were left out of the analysis due to their specific duties and importance. This left a total of 397 vehicles in the city's fleet that could be analyzed for efficiency improvements.

To calculate the emissions reductions associated with converting a city fleet vehicle to a hybrid, it was important to look at the type of vehicle. The fleet vehicles were split into sedans, SUVs, trucks, and vans. Make, model, age, and mileage data were combined to calculate monetary values for each vehicle in the city fleet. This was done by using the online Kelley Blue Book to determine the trade-in value of the car.[124] The cars were assumed to have base features and be in 'Good' condition. Estimates of lifetime and yearly mileage were calculated using the data. All of this data was combined to find the statistics associated with an 'average vehicle', which was an average of all of the vehicles in the database. These statistics are shown in Table 8.38.

Table 8.38. Summary Data on City Vehicle Fleet

	[unit]	Sedans	SUVs	Trucks	Vans
Quantity	#	61	27	270	39
Value	$	$4,421	$6,281	$6,639	$4,923
City MPG	mpg	21.6	15.6	15.4	14.7
Hwy MPG	mpg	31.0	20.6	20.4	19.6
Yearly mileage	mi	4,720	7,804	7,096	5,452

Next, a suitable replacement vehicle was found for each type of car. Each traditional vehicle would be replaced with a hybrid vehicle. The hybrids were found on the government's fuel economy website.[125] For sedans, the 2009 Ford Escape Hybrid FWD was chosen. While it is not a traditional sedan, it is the American-made car with the lowest carbon footprint, estimated at 5.7 tons per year. The city has a policy where only American made vehicles can be purchased. For the SUV category, the 2009 Ford Escape Hybrid 4WD was chosen. This four wheel drive version of the Escape should be able to serve the needs of the fleets SUVs. For trucks, the 2009 Chevrolet Silverado 15 Hybrid 2WD was chosen as the replacement hybrid, since it was the American-made truck with the lowest carbon footprint. For the vans, there was no comparable hybrid model available. The vans that the city has in its fleets are cargo vans.

With this information on the hybrid replacements, calculations were done to find the fuel savings, monetary savings, and emissions reductions associated with the switch of one vehicle to a hybrid. This data is presented below in Table 8.39.

The net cost of conversion considers the cost of selling a current vehicle for the average trade-in price, while purchasing a new hybrid vehicle for the average retail price. The annualized cost determines the expected annual cost of switching to the hybrid over its lifetime. This number assumes a 20 year lifetime and includes the cost savings associated with reduced gas use. The max emissions reduction is a value that assumes that all of the city's fleet is converted to hybrids.

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[124] http://www.kbb.com/

[125] http://www.fueleconomy.gov/feg/hybrid_sbs.shtml

Table 8.39. Summary of Emissions Reductions from Hybrid Vehicles

	[unit]	Sedans	SUVs	Trucks
Yearly gas savings	gallons / veh	380	584	1,271
Yearly emissions savings	tons / veh	3.4	5.1	11.2
Net cost of conversion	$ / veh	$25,949	$25,839	$23,731
Annualized cost	$ / veh	$2,693	$3,113	$4,366
Max emissions reductions	tons	204	139	3,024
$/ ton eCO2 reduced	$ / ton	$804	$606	$390

This is reasonable considering that the most recent census found Pittsburgh to have approximately 30,000 trees within its city limits. This max constraint would significantly increase this number, but is in the same order of magnitude. The overall data and information above is summarized in Table 8.40, Table 8.41, and Table 8.42.

Table 8.40. Summary Table for Hybrid Sedans in City Fleet

Capital cost	26,000	$
Life span	20	years
Discount rate	4	%
Fuel savings per year	380	gal/year
Fuel saving costs	-775	$/year
Annualized costs	1,133	$/year
eCO2 savings	3.4	tons/year
Cost/ton eCO2 reductions	333	$/ton

Table 8.41. Summary Table for Hybrid SUVs in City Fleet

Capital cost	26,000	$
Life span	20	years
Discount rate	4	%
Fuel savings per year	584	gal/year
Fuel saving costs	-1,191	$/year
Annualized costs	713	$/year
eCO2 savings	5.1	tons/year
Cost/ton eCO2 reductions	140	$/ton

Table 8.42. Summary Table for Hybrid Trucks in City Fleet

Capital cost	24,000	$
Life span	20	years
Discount rate	4	%
Fuel savings per year	1,271	gal/year
Fuel saving costs	-2,593	$/year
Annualized costs	-834	$/year
eCO2 savings	11.2	tons/year
Cost/ton eCO2 reductions	-74	$/ton

These tables each represent summary statistics for the conversion of a single vehicle to a hybrid. The max constraint for each of these actions is simply the current number of vehicles of that type in the city vehicle fleet. This would give the upper-bound statistics for emission reductions.

9. **Developing Climate Action Plans**

The climate impacts of cities cross public, private, and municipal boundaries, complicating an explicit documentation of the costs and effectiveness of local policies for greenhouse gas (GHG) reductions.

At a minimum, a climate action plan should aim to maximize total GHG reductions at minimal initial and lifetime social costs. Recommendations should be actionable and match reduction goals. Ideally, the costs and benefits proposed by the action plan would be accounted for by sector and jurisdiction, with a cost and emission reduction schedule developed for each responsible authority. However, given that CAPs published to date have been rough road maps for GHG reductions and GHGs are not explicitly regulated, such detail cannot currently be expected.

This report presents several techniques that can be used to improve the design and implementation of CAPs. We leverage the database of quantified action items developed in Section 8 in a life-cycle cost framework to identify the costs and effectiveness of various program scales. We also quantify the impact of jurisdiction by considering only municipal action items relative to societal action items.

9.1. **Quantifying Action Items**

At least three dimensions of each action item must be defined before rigorous design and evaluation of a climate action plan:

(1) the initial cost,
(2) the annualized cost effectiveness, which takes into account annual operating costs, savings, and emission impacts, and
(3) the maximum effectiveness, which reflects the physical constraint associated with action item. A fourth dimension may be added: life cycle GHG impacts that reflect material production, transportation, and disposal. This fourth dimension may also be incorporated into the annualized cost effectiveness by annualizing life cycle impacts. This report does not reflect life cycle impacts on emissions.

Section 8 describes how to prepare an appropriate database of action items for technical retrofits or technical interventions. Section 7.6 provides recommendations on how to extend this analysis to accommodate behavioral action items.

For those items quantified in Section 8, Figure 9.1 demonstrates the three dimensions of CAP action items – annualized cost effectiveness, initial cost, and total maximum effectiveness. Figure 9.1 reflects pricing and climate conditions local to Pittsburgh.

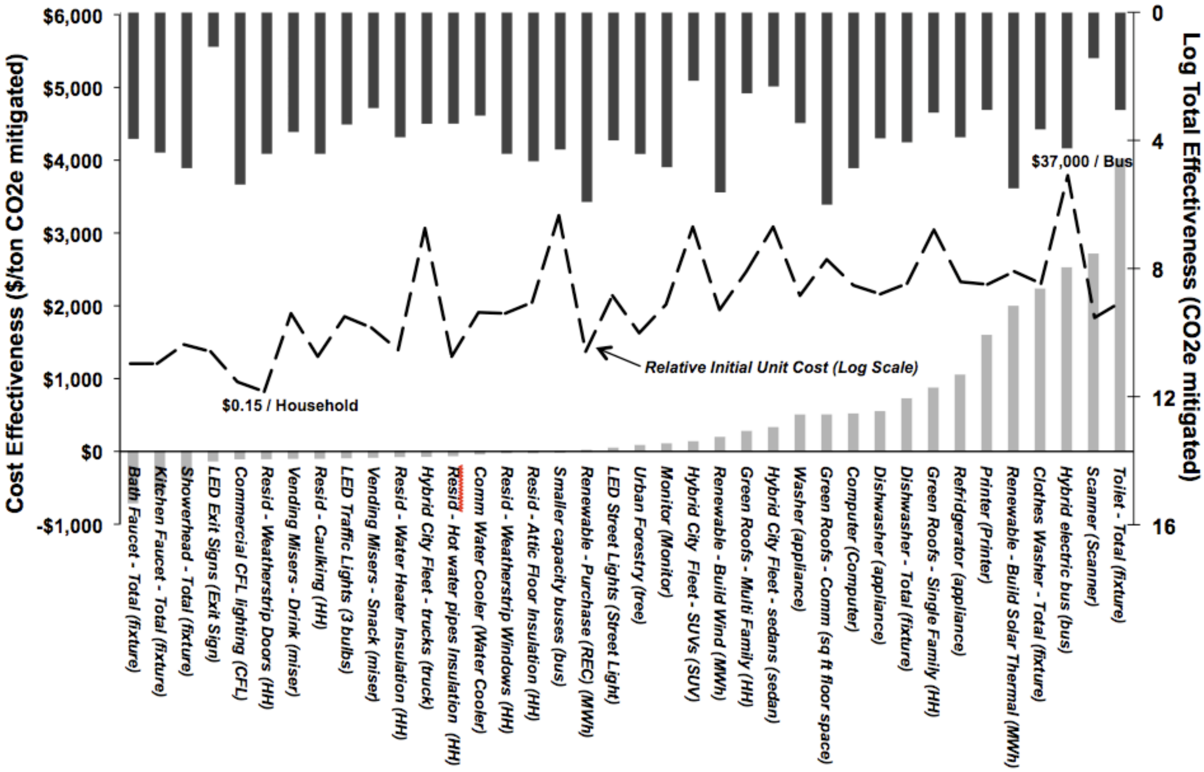

Figure 9.1: Three-Dimensions of 36 Action Items for Pittsburgh, PA

The left y-axis reflects the annualized cost effectiveness, which is shown by the bottom bar chart. Items below 0 reduce emissions and generate savings. The dashed line shows the relative initial unit cost on a log scale. The minimum and maximum initial unit costs (weather-stripping doors and hybrid buses, respectively) are labeled. The y-axis on the right pertains to the top bar chart, which shows the maximum total effectiveness on a log scale. Data reflect the unit in parenthesis that accompanies the description of the action item along the x-axis.

In Figure 9.1, consider the action item that recommends replacing exit sign incandescent bulbs with LED bulbs (shown as fourth from the left). Per unit bulb replacement, retrofitting exit signs in Pittsburgh with LEDs is relatively cost effective (indicated by bottom bar chart) and inexpensive (indicated by dashed line); however, very little GHG emissions can be reduced even if all exit signs (indicated by top bar chart).

An action item database includes items such as those shown in Figure 9.1 and defines the GHG reduction and cost characteristics necessary to estimate the initial cost, operating cost, net present value, and GHG reduction potential of any CAP. In other words, such a database defines the physical constraints associated with GHG reductions as well the initial and operating cost curves for GHG mitigation.

For a more advanced analysis, the database of action items could be extended to reflect costs and benefits by sector or jurisdiction. The costs and effectiveness by sector or jurisdiction must be known and accounted for appropriately. For accurate accounting, some action items may need to be split across jurisdiction.

Finally, each action item in the database should be represented by a functional unit that is easily scaled. For example, building lighting action items should be documented by bulb or fixture instead of by room or building. The functional units for the database shown in are represented in parentheses along the x-axis labels.

9.2. Climate Action Plan Design

The database of action items described in Section 9.1 serves as the heart of climate action plan design: thus the more exhaustive the database, the better than CAP will be. Such rationale supports extending the inventory boundary to reflect all GHG intensive activities associated with the City, as well as quantifying the costs and effectiveness of behavioral action items.

An accurate database can be used in a qualitative or quantitative fashion to improve the analytical rigor of CAP design and implementation. For example, action items could be loosely prioritized by stakeholders based upon cost and effectiveness performance. This approach has the advantage of mixing action item performance data with important subjective factors, such as feasibility, as well informally accommodating the complexity of jurisdiction over costs and benefits. It also better informs decision making without the need for exhaustive resources.

We recommend a more rigorous analysis, such applying spreadsheet tools to an exhaustive database of action items to evaluate CAP design. For this study, the *solver* tool in MS Excel ® is used to optimize GHG reductions constrained by either an initial budget or lifetime costs.

9.3. Optimization

The multi-dimensional nature of GHG action items and the potential combinations of action items in CAP design render traditional life-cycle cost analysis difficult. Simple optimization techniques can be used to evaluate several CAP scenarios to better understand the tradeoffs between various CAP objectives: initial costs, lifetime costs, and GHG reductions.

Optimization requires defining three criteria (1) the objective (2) the constraints and (3) the decision variables. An example of optimization criteria relative to CAP design is:

- Objective: Maximize GHG reductions
- Constraints: (1) Limited initial budget (or limited lifetime costs)
  (2) Number of action items restricted by physical limitation, eg, there are a limited number of light bulbs that can be replaced
- Decision variables: Number of action item expenditures

The following sections present optimization results for Pittsburgh's CAP using the database of action items described in Section 8. Life cycle cost parameters represented in the following analyses include a 20-year planning horizon, a 4% discount rate for life-cycle cost analyses, an electricity cost of $0.10 per kWh, a natural gas price of $11.38 per Mcf, a gasoline price of $2.40 per gallon, a diesel fuel price of $2.75 per gallon, and a water price of $6.99 per kgal.

9.4. Sample Optimization Results for Pittsburgh

Figure 9.2 and Figure 9.3 demonstrate the tradeoff between emission reductions, initial costs, and lifetime costs for two optimization scenarios: (1) maximizing emissions reductions given an initial budget constraint and (2) minimizing lifetime costs, ie, net present value, given a targeted emissions reduction. Note that the initial cost denominations shown in each of these figures are not consistent as a result of optimization routines.

Figure 9.2 and Figure 9.3 each show three parameters: the CAP initial cost on the x-axis, the greenhouse gas emissions reductions expressed as a percent relative to current emissions on the left y-axis, and the 20-year net present value of the CAP on the right y-axis. The stacked bar chart, which matches the left y-axis, shows the emissions reduction for each action item selected as part of the optimization routine. For example, consider Figure 9.2, which shows results when CAPs are designed to maximize emissions given a limited initial budget. Figure 9.2 indicates that spending $5M initially on CAP action items will result in a 4% emissions reduction through (1) purchasing RECs and (2) weather-stripping doors. Over a 20-year period these two action items will generate approximately $6M in savings, or the 20-year net present value is $6M.

The following trends are demonstrated on Figure 9.2 and Figure 9.3:

- The performance of GHG mitigation action items varies considerably both within and across the optimization scenarios shown in each figure. The selected supply side alternatives – such as the provision of renewable energy – dominate the emissions reductions when minimizing initial costs. The selected demand management technologies – such as home weatherization and water conservation – dominate the preferred alternatives when minimizing lifetime costs. These results make intuitive sense considering that supply side alternatives result in no energy savings.
- At higher reduction levels, the selected demand side action items demonstrate less GHG reduction potential than supply side action items.
- As action items become exhausted with increasing GHG reductions, both optimization solutions converge and are nearly identical at a 30% reduction level.
- Constraining CAP design solely by initial costs severely limits opportunities to generate savings and may create long-term costs as demonstrated by the net present value curves in each figure.
- Both optimization scenarios demonstrate that savings varies with initial costs and GHG reductions, generally increasing with increasing reduction to a peak value then diminishing beyond the peak. This pattern is a result of the limited fraction of action items that both reduce GHGs and generate savings.
- Very few of the selected action items fall within the City's immediate jurisdiction.

9.5. Jurisdictional Boundary Analysis

GHG emissions in cities cross many jurisdictions. The costs and benefits of action items follow a similarly complicated multi-jurisdictional structure. As a result, designing and implementing a cost-effective CAP may require extensive coordination amongst municipal authorities, business owners, homeowners, and utilities.

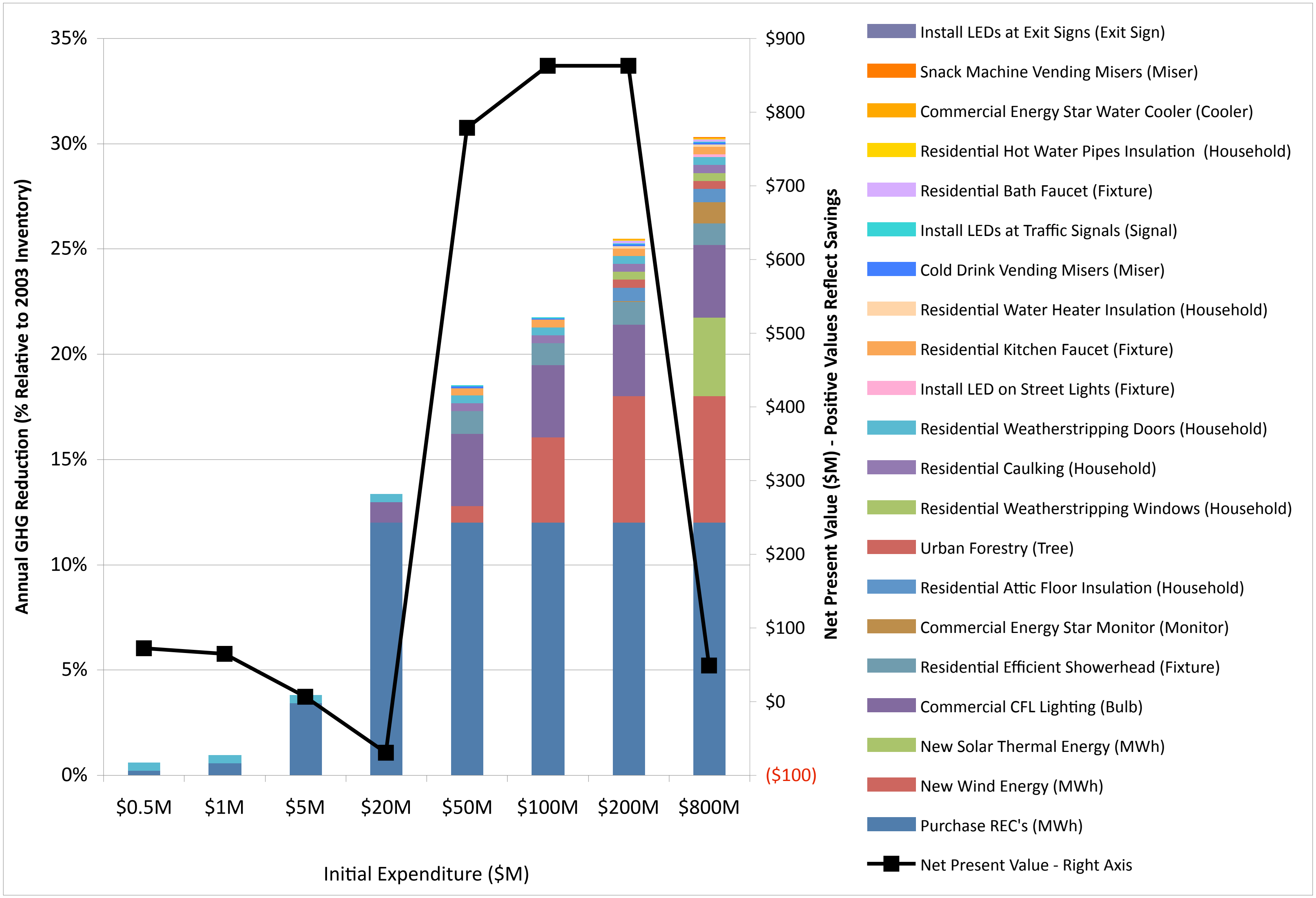

Figure 9.2: CAP Scenario Analysis – Maximize Emission Reductions Given Initial Budget Constraint
Property viewed in color. Bar stacks match order shown in legend. Net present value matches right axis. Note initial budgets on x-axis do not match those on Figure 9.3.

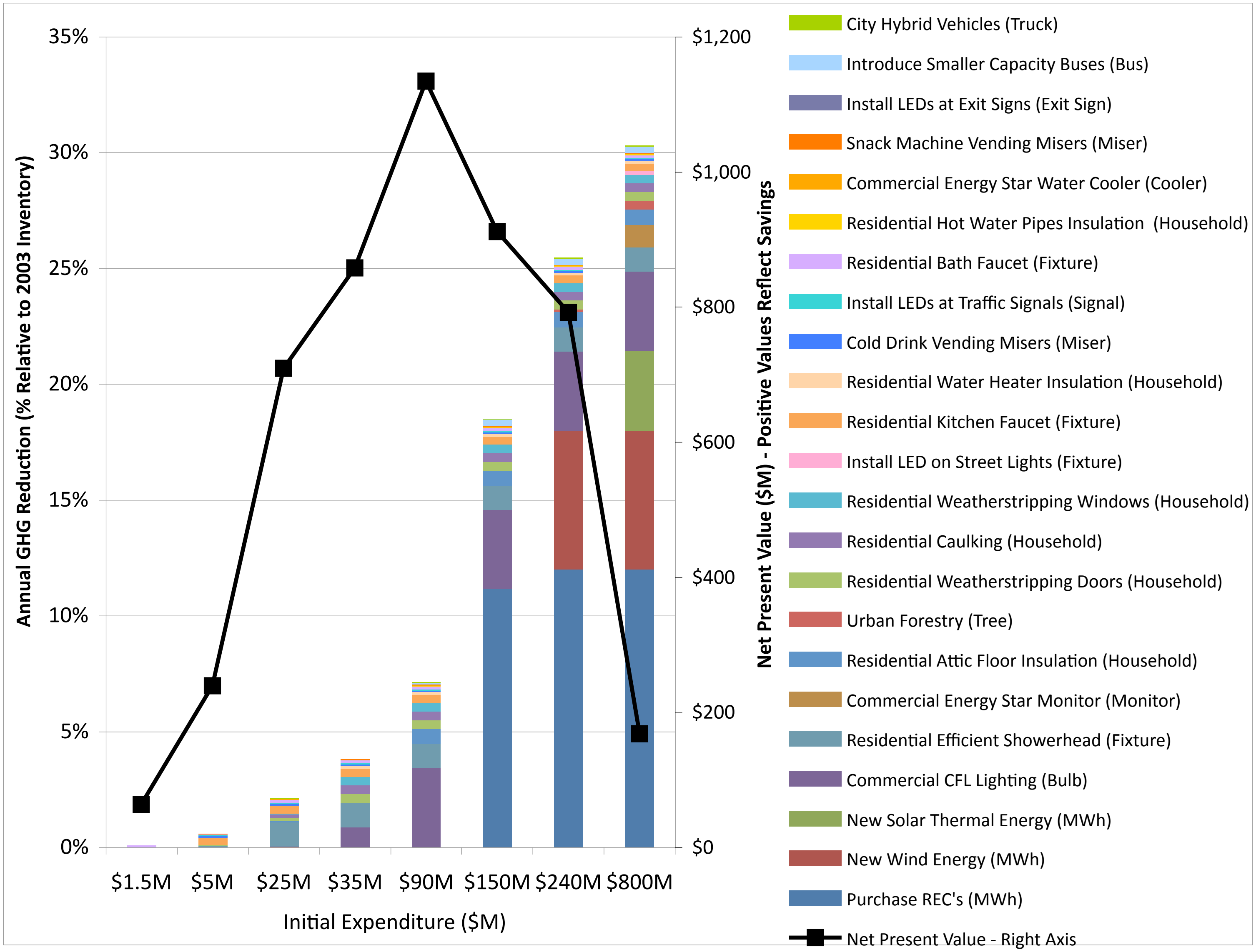

Figure 9.3: CAP Scenario Analysis – Minimize Lifetime Costs Given Targeted Reduction

Property viewed in color. Bar stacks match order shown in legend. Net present value matches right axis. Note initial budgets on x-axis do not match those on Figure 9.2.

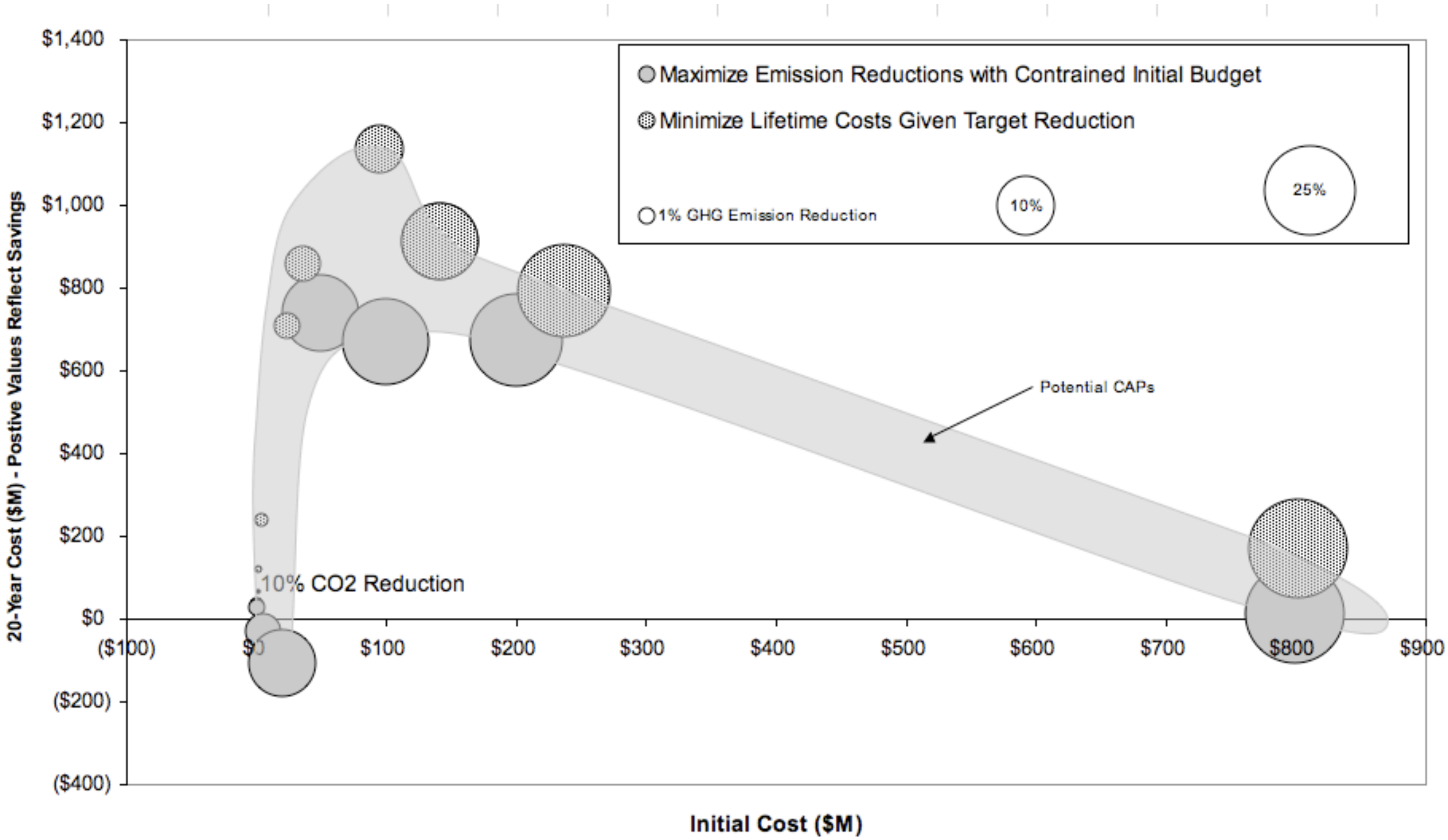

Figure 9.4: Summary of Optimization Scenarios

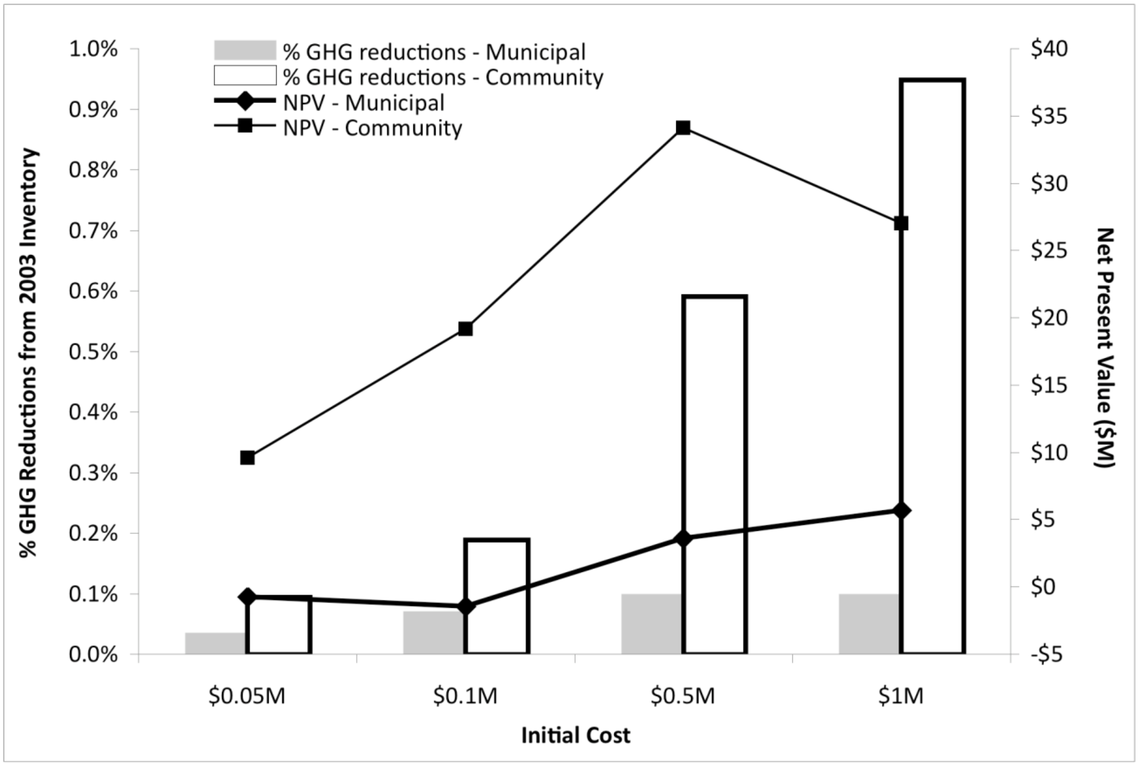

Figure 9.5: Impact of Limiting CAP to Municipal Jurisdiction – Maximizing Reductions Given Initial Budget

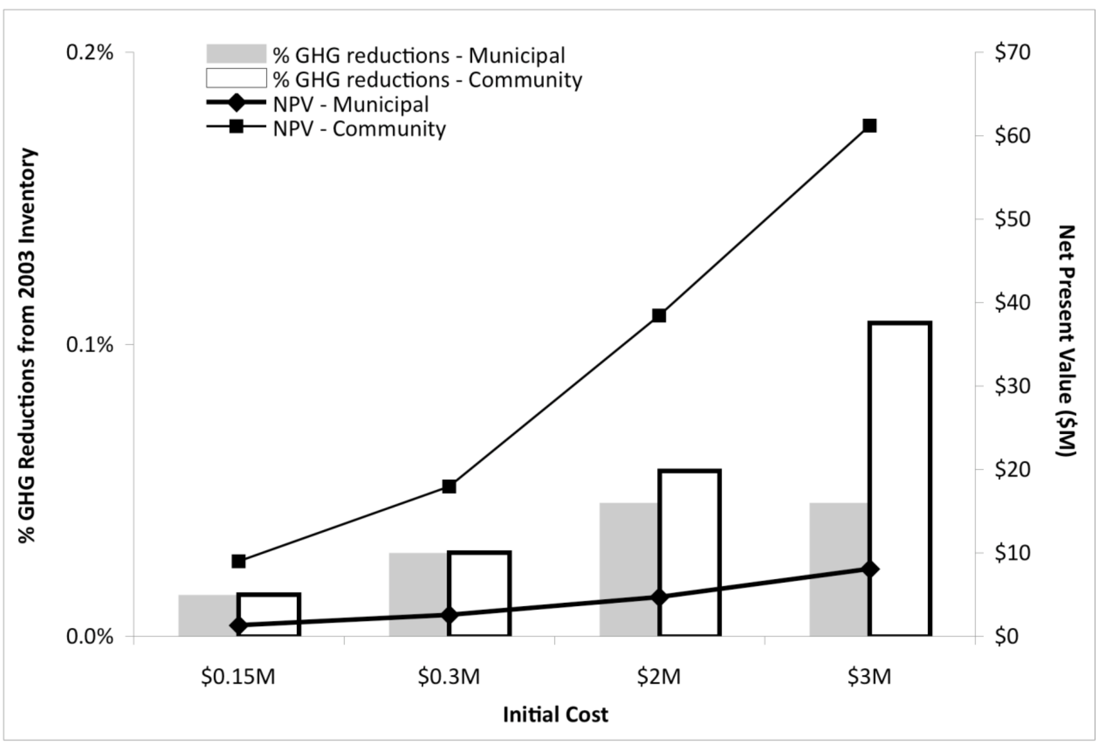

Figure 9.6: Impact of Limiting CAP to Municipal Jurisdiction – Minimizing Lifetime Costs Given Target Reduction

Most CAPs and supporting GHG inventories follow ICLEI's convention of delineating inventories and action items between the "municipal' (or city government) boundary and the "community" (or city-wide) boundary. This not only complicates inventory analysis, but it may result in the design of inefficient CAPs.

Figure 9.5 and Figure 9.6 show that CAPs limited to the municipal jurisdiction demonstrate fewer emissions reductions and less long-term savings than those that are extended to included the entire community. These results are direct consequence of the fact that the community action items quantified in Section 8 are more extensive and effective than municipal action items.

As a result, cities charged with designing effective CAPs may consider looking beyond their immediate municipal jurisdiction to achieve effective CAP design.

9.6. Summary of CAP Analysis

Figure 9.4 and Figure 9.7 summarize performance measures for the two optimization scenarios: (1) maximizing emissions reductions given an initial budget constraint and (2) minimizing lifetime costs, i.e., net present value, given a targeted emissions reduction. These figures demonstrate that:

- Appropriately designed CAPs can both substantially mitigate emissions as well as generate significant savings, with 7% and 25% emission reduction targets corresponding to $1.1B and $800M savings, respectively, over a 20-year period.
- However, CAPs that primarily target long-term savings typically initially cost 3-10 times more than CAPs that optimize emission reductions over initial costs, with some of the latter program designs generating long-term costs as opposed to savings.
- If optimizing reductions over initial costs, every 1% emission reduction roughly requires $1M of initial capital up to a total reduction of 10%.
- If optimizing over lifetime costs, every 1% emissions reduction roughly requires $10M or initial capital up to a total reduction of 1%.
- Beyond an emission reduction target f 25%, the two optimization scenarios behave nearly identical as more action items are exhausted.
- Confining CAPs to the municipal jurisdiction may result in lost opportunities for long-term social savings as well as less cost effective reductions

We recognize the costs presented in Figure 9.2 to Figure 9.7 ($50K-$800M) are significant municipal expenditures and may be much higher than those being considered by the City of Pittsburgh. The intent of presenting optimization scenarios and results is not to suggest specific line items for budgeting, but to (1) outline a repeatable analysis for the design of future CAPs (2) qualitatively demonstrate trade-offs between CAP design parameters and outcomes and (3) provide planning level trends and guidelines for decision makers.

We recommend some repeatable and transparent analysis be conducting when designing CAPs. The techniques presented here, which leverage life-cycle costing techniques in a numerical optimization framework, as well as those presented in Section 8 can be used in a qualitative or quantitative way to better inform CAP development.

We further recommend that the City consider action items beyond their immediate jurisdiction to achieve the most cost effective reductions as well as generate the most social savings. Results demonstrate that the following types of action items demonstrate both low initial costs as well as generate savings:

- Weatherizing residential buildings
- Retrofitting residential buildings with efficient water fixtures
- Retrofitting municipal and commercial lighting fixtures with CFLs
- Installing misers on vending machines

These types of interventions represent 14 action items that account for 7% of community-wide GHG emissions, would cost $80M for complete execution in the City, and generate approximately $1B of social savings over 20 years

It should be emphasized that our analysis is limited to those action items quantified in Section 8. While the trends presented in the figures shown throughout Section 9 match intuition, details would likely change with the development of a more exhaustive database of action items. For example, optimization of traffic signal timing would likely result in significant cost-effective emissions reduction. Including this in the analysis would affect our results.

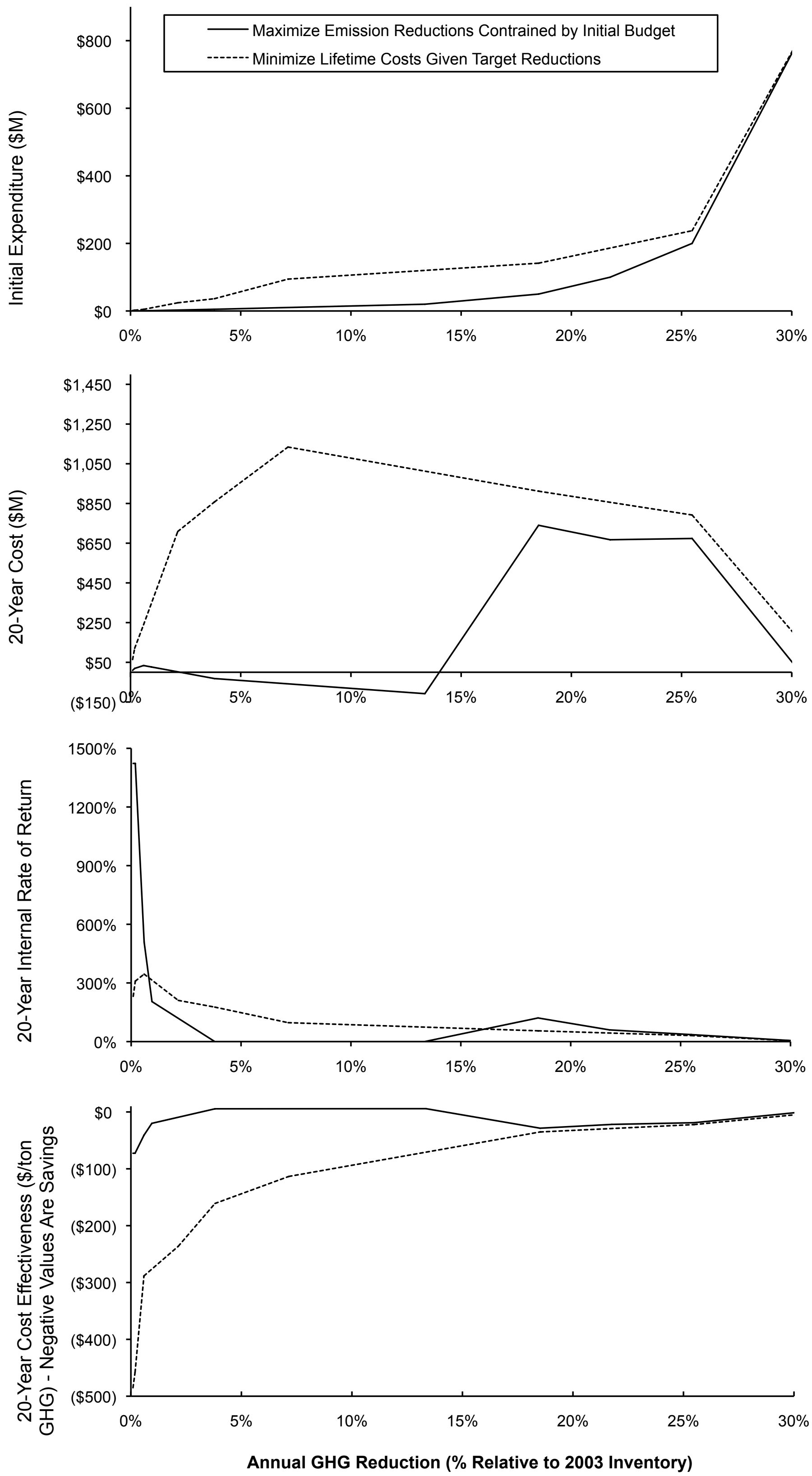

Figure 9.7: Select CAP Performance Metrics from Optimization Scenarios

10. Appendix 1. Summary Tables from 2009 Inventory Verification Estimate

Table 10.1. GIS Building

Code	Description	No Floors	Bldg Footprint (sf)	Floor space (sf)	% of Total
AP	Mixed Use Planned Unit Development	1.25	608,000	760,000	0.40%
CP	Commercial Planned Unit Development	1.25	1,420,000	1,770,000	0.94%
DR-A	Downtown Riverfront District A	10	368,000	3,680,000	1.96%
DR-B	Downtown Riverfront District B	10	1,060,000	10,600,000	5.65%
DR-C	Downtown Riverfront District C	10	398,000	3,980,000	2.12%
GT-B	Golden Triangle District B (Strip only)	10	256,000	2,560,000	1.36%
GT-C	Golden Triangle District C (Strip only)	10	39,700	397,000	0.21%
HC	Highway Commercial District	1.25	876,000	1,090,000	0.58%
LNC	Local Neighborhood Commercial	1.25	10,700,000	13,400,000	7.15%
NDO	Neighborhood Office District	1.25	60,400	75,400	0.04%
OPR-A	Oakland Public Realm District A	7	92,800	650,000	0.35%
OPR-B	Oakland Public Realm District B	7	320,000	2,240,000	1.19%
OPR-C	Oakland Public Realm District C	7	505,000	3,540,000	1.88%
OPR-D	Oakland Public Realm District D	7	344,000	2,410,000	1.28%
UNC	Urban Neighborhood Commercial District	2	1,610,000	3,220,000	1.71%
EMI	Educational/Medical Institution District	5	6,840,000	34,200,000	18.20%
GPRA	Grandview Public Realm Sub district A	0.5	43,300	21,700	0.01%
GPRB	Grandview Public Realm Sub district B	0.5	161,000	80,600	0.04%
GPRC	Grandview Public Realm Sub district C	0.5	99,800	49,900	0.03%
Central Business District		0	20	5,160,000	103,000,000
		Total	31,000,000	188,000,000	

Table 10.2. Commercial Floor Space Estimates

Sector	Boundary	Buildings	mil sq ft	Scale method	Factor
Retail	Beaver/Butler/Allegheny/ Washington/Westmoreland	>5,000 sf	95.6	Provided directly by CBRE	-
	Allegheny	>5,000 sf	55.4	By population	0.58
	MSA	>5,000 sf	105		1.10
	Allegheny	All	69	Using CBECS distributions of bldg size &	1.25
	MSA	All	131	allowing for some missing bldg's in CBRE data	1.25
Office	Allegheny	>10,000 sf	72.9	Provided directly by CBRE	-
	MSA	>10,000 sf	138	By above retail proportions	1.89
	Allegheny	All	91.1	Using CBECS distributions of bldg size &	1.25
	MSA	All	173	allowing for some missing bldg's in CBRE data	1.25
All	Allegheny	All	229	Scaled using CBECS distribution of bldg activity	1.43
	MSA	All	435	Scaled using CBECS distribution of bldg activity	1.43
	City of Pittsburgh	All	59.8	Scaled by population (using Allegheny Co)	0.26

Table 10.3. Pittsburgh MSA Estimated GDP[126,127]

Industry	**GDP (Est. $Mil)**
All industry total	89024
Private industries	81652
NATURAL RESOURCE AND MINING	1125
Agriculture, forestry, fishing, and hunting	102
Crop and animal production (Farms)	94
Forestry, fishing, and related activities	8
Mining	1023
Oil and gas extraction	247
Mining, except oil and gas	528
Support activities for mining	247
CONSTRUCTION	4085
Utilities	2,475
Construction	4085
MANUFACTURING	12478
Manufacturing	12478
Durable goods	0
Wood product manufacturing	252
Nonmetallic mineral product manufacturing	919
Primary metal manufacturing	2753
Fabricated metal product manufacturing	1022
Machinery manufacturing	935
Computer and electronic product manufacturing	460
Electrical equipment and appliance manufacturing	539
Motor vehicle, body, trailer, and parts manufacturing	539
Other transportation equipment manufacturing	0
Furniture and related product manufacturing	102
Miscellaneous manufacturing	571
Nondurable goods	0
Food product manufacturing	1186
Textile and textile product mills	108
Apparel manufacturing	55
Paper manufacturing	539
Printing and related support activities	709
Petroleum and coal products manufacturing	252
Chemical manufacturing	1078
Plastics and rubber products manufacturing	459

126 http://www.bea.gov/regional/gdpmetro/
127 http://www.census.gov/epcd/cbp/index.html

Table 10.4. Pittsburgh GDP Commercial Floor Space Estimate

Industry	NAICS	Est. Employees	Est. GDP ($Mil)	Floor Space (sf/$GDP)	Floor Space (sf)
Utilities	22	7,500	2,475	0.0026	6,300,000
Wholesale trade	42	51,084	4,961	0.0025	13,000,000
Retail trade	44, 45	131,835	5,759	0.0121	69,000,000
Warehousing & storage	493, 492	8,250	708	0.0036	2,500,000
Publishing including software	511	7,500	707	0.0010	700,000
Motion picture & sound recording industries	512	1,750	165	0.0018	300,000
Broadcasting & telecommunications	513	15,604	1,471	0.0018	2,700,000
Information & data processing services	514	7,500	707	0.0010	700,000
Federal Reserve banks, credit & related services	521, 522	27,650	3,547	0.0005	1,700,000
Securities, commodity contracts, investments	523	7,500	962	0.0007	630,000
Insurance carriers & related activities	524	19,635	1,893	0.0010	2,000,000
Funds, trusts, & other financial vehicles	525	10	1	0.0005	600
Real estate	531	7,500	854	0.0003	260,000
Rental/leasing services/leasers of intangible assets	532, 533	4,902	558	0.0014	790,000
Professional & technical services	54	68,555	6,346	0.0026	16,000,000
Management of companies & enterprises	55	29,749	2,008	0.0026	5,100,000
Administrative & support services	561	54,443	2,027	0.0026	5,200,000
Waste management & remediation services	562	2,836	106	0.0015	160,000
Educational services	61	44,972	*15,659*	0.0122	190,000,000
Ambulatory health care services	621	48,571	3,466	0.0015	5,100,000
Hospitals & nursing & residential care facilities	622, 623	106,898	3,724	0.0108	40,000,000
Social assistance	624	17,500	610	0.0122	7,400,000
Performing arts, museums, & related activities	711, 712	11,250	532	0.0039	2,100,000
Amusement, gambling, & recreation	713	7,500	354	0.0032	1,100,000
Accommodation	721	9,681	402	0.0031	1,200,000
Food services & drinking places	722	76,005	1,508	0.0025	3,800,000
Other services, except government	81	55,701	2,280	0.0091	21,000,000
Transportation (for indirect only)					
Air transportation	481	17,500	1,503	0.0011	1,600,000
Rail transportation	482	0	0	0.0000	0
Water transportation	483	750	64	0.0009	55,000
Truck transportation	484	9,235	786	0.0020	1,600,000
Transit and ground passenger transportation	485	7,500	220	0.0032	700,000
Pipeline transportation	486	750	64	0.0005	29,000
Other transportation and support activities	487	3,925	337	0.0072	2,400,000
	Total	867,616	63,791		410,000,000

Table 10.5. EIA Building Energy Consumption Factors for 2003

Total Energy Intensity (BTU/sf)	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Zone Average	94.2	102.6	99.4	78.6	78.6
Northeast	82.2	99.8	108.0	N	N
New England	63.1	114.5	N	N	N
Middle Atlantic	94.2	89.4	108.0	N	N
Midwest	97.0	105.1	70.5	N	N
East North Central	103.8	109.6	N	N	N
West North Central	88.9	74.6	70.5	N	N
South	N	N	99.7	86.6	75.8
South Atlantic	N	N	101.4	89.0	77.7
East South Central	N	N	112.3	78.5	98.9
West South Central	N	N	Q	86.7	73.0
West	99.0	98.2	96.4	63.5	121.0
Mountain	99.9	115.5	N	N	112.9
Pacific	95.1	78.8	96.4	63.5	Q
Electricity Energy Intensity (BTU/sf)	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Zone Average	41.3	46.8	52.2	52.2	63.1
Northeast	35.2	41.6	46.1	N	N
New England	25.3	47.4	N	N	N
Middle Atlantic	41.3	37.9	46.1	N	N
Midwest	40.3	48.1	42.7	N	N
East North Central	37.5	50.5	N	N	N
West North Central	43.3	33.8	42.7	N	N
South	N	N	62.8	56.0	61.1
South Atlantic	N	N	64.2	60.4	65.5
East South Central	N	N	67.2	46.1	66.9
West South Central	N	N	Q	51.5	58.0
West	48.8	53.9	49.5	44.7	93.5
Mountain	47.8	53.9	N	N	92.8
Pacific	53.6	53.9	49.5	44.7	Q
Natural Gas Energy Intensity (BTU/sf)	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Zone Average	55.2	52.2	40.9	33.0	27.1
Northeast	52.7	50.9	38.6	N	N
New England	Q	47.1	N	N	N
Middle Atlantic	53.2	54.0	38.6	N	N
Midwest	55.1	52.0	53.3	N	N
East North Central	58.7	53.3	N	N	N
West North Central	49.6	Q	53.3	N	N
South	N	N	42.4	36.7	26.1
South Atlantic	N	N	35.6	36.1	22.1
East South Central	N	N	Q	34.5	44.0
West South Central	N	N	Q	39.3	25.7
West	56.6	57.5	34.0	26.4	39.0
Mountain	59.2	66.9	N	N	28.8
Pacific	46.0	34.7	34.0	26.4	79.2

Fuel Oil Energy Intensity (BTU/sf)	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Zone Average	0.0	3.7	6.3	0.0	0.0
Northeast	0.0	7.2	23.4	NA	NA
New England	NA	19.9	NA	NA	NA
Middle Atlantic	0.0	0.0	23.4	NA	NA
Midwest	1.7	5.0	0.0	NA	NA
East North Central	7.6	5.8	NA	NA	NA
West North Central	0.0	NA	0.0	NA	NA
South	NA	NA	0.0	0.0	0.0
South Atlantic	NA	NA	1.7	0.0	0.0
East South Central	NA	NA	NA	0.0	0.0
West South Central	NA	NA	NA	0.0	0.0
West	0.0	0.0	12.9	0.0	0.0
Mountain	0.0	0.0	NA	NA	0.0
Pacific	0.0	0.0	12.9	0.0	NA