EVALUATION OF DURHAM CITY COUNTY GREENHOUSE GAS REDUCTION INITIATIVES

by

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April 2014

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

2014

Contents

1. Introduction

In recent years, studies have increasingly shown that anthropogenic climate change is occurring on a global level (IPCC 2007). Main drivers of climate change are greenhouse gases, including carbon dioxide (CO_2), methane (CH4), ozone (O3), nitrous oxide (N_2O), and other halocarbons. These greenhouse gases have long lifetimes in the atmosphere and can disrupt the energy balance of the climate system if concentrations exceed previously observed ranges. With increasing concentration of greenhouse gases, the average global temperature is predicted to increase by several degrees by the end of the century (IPCC 2007). This increase of energy in the climate system may activate positive feedback systems that can amplify natural systems such as stronger and more frequent natural disasters, redistribution of natural resources, coastal erosion, and water scarcity.

One way to address and to better understand greenhouse gas emissions is to track where and how these gases are emitted. Through the United Nations Framework Convention on Climate Change (UNFCCC), national emission inventory emerged as a tool to track anthropic greenhouse gas sources. IPCC created a methodology framework used to aggregate emissions from several main categories, including energy, forestry, agriculture, livestock, industrial processes, and product use (IPCC 2006). Though this framework can work on a national or state level, it does not help pinpoint geographical locations where emissions are the highest.

Local emissions inventory can be completed on a city or metropolitan level to drive better policy decisions. Having a local greenhouse gas inventory can also help evaluate the effectiveness of previous strategies and identify new methods for greenhouse gas reduction. However, with a smaller scope, establishing a boundary for emission calculation can be difficult and often inconsistent between different local emissions inventories. The Cities for Climate Protection (CCP) established by International Council for Local Environmental Initiatives (ICLEI) created a standardized framework for greenhouse gas inventory on a local level.

An emissions inventory can help formulate comprehensive greenhouse gas reduction plans. In addition to reducing emissions, a greenhouse gas reduction plan also has benefits in other areas of local government management. Efficiency increase can help reduce the amount of fossil fuel combustion and in turn improve the air quality of the surrounding area. The greenhouse reduction plan also makes business sense because it can help reduce long term cost from lowered energy consumption. Furthermore, these benefits can attract community attention and improve awareness education in schools and neighborhoods.

2. Literature Review

Previous literature takes a broad approach by examining different aspects of greenhouse gas emissions and measurements at the national and local levels. Kennedy and et.al. (2010) studied the methodology to measure greenhouse gas (GHG) emissions in ten cities or city-regions, such as Los Angeles County, Cape Town, Bangkok, etc. In this study, equations for components of GHG inventory were developed such as electricity; heating and industrial fuels; ground transportation fuels; air and marine fuels; industrial processes; and waste. The authors also addressed the measurement boundary of GHG emissions for cities and city-regions, which helps define the scope of our study.

Kennedy, Demoullin, and Mohareb (2012) developed further studies of the city performance of reducing greenhouse gas emissions through collecting GHG emission inventories of six major cities and their respective nations. Having examined the percentage change of GHG emissions from Energy (Stationary Combustion, Mobile Combustion, and Fugitive Sources), Industrial Process, and Waste sections between 2004 and 2009, and further compared these cities and nations with per capita value, they found that these six cities are reducing their per capita GHG emissions faster than their country level, mainly through the mitigation of stationary combustion. The study also raised some valuable points for future study, that is, whether to take aviation emission and exported waste into account since they generate GHG emission outside of the city's scope.

Other researchers focused on problems and future opportunities of carbon emission policies at the local level. Betsill (2001) summarized the opportunities and obstacles for mitigation of climate change in municipal level, referring to the Cities for Climate Protection (CCP) campaign conducted by ICLEI which involves over hundreds of cities in the U.S. The author concluded that cities prefer creating co-benefits from GHG reductions, such as financial and social benefits rather than focusing on environmental benefits solely. The study found that institutional barriers are the main obstacles for municipal action so city governments should increase their administrative capacity and financial resources.

Although many scholars have conducted studies about methodologies to measure GHG emissions and mitigation policies, there has been little attention to local level GHG inventory to keep track of performance and to accurately measure emissions with a standardized methodology. Dodman (2009) identifies several problems with citywide greenhouse gas inventories, especially in the large cities. Most methodologies currently use production based methods, where greenhouse gas is counted at the point of production, but do not take into account where the production item goes. The emission can only be attributed to a location from or location to description, but does not count both. The results from production-based methodology exaggerates emissions from the economy and consumption behavior, and places more blame on cities with high physical productivity rather than service oriented cities. Consumption based methodology is a calculation of carbon footprint, which is more reflective of actual emissions, but it has a higher level of uncertainty due to inadequate information and a high degree of variability. Cities are not the main culprits of greenhouse gas emissions because they are highly concentrated and more efficient. However, they can become drivers for emission reduction with the correct policies based on a greenhouse gas inventory.

Future studies should focus on city specific inventories to compile data of performances by case studies. Therefore, policy makers create evidence-based policies for a medium and long term horizon. For instance, Avignon et al (2010) describes the greenhouse gas inventory as a method of public policy. Using Rio de Janeiro and San Paulo greenhouse gas inventories as case studies, individual sectors were analyzed based on methodology and the types of data acquired. The layout of this paper is ideal for the Durham Greenhouse Gas Inventory Update because it focuses on specific areas of the city and analyzes the impact of emissions.

3. Previous Durham Project with ICLEI

Durham, the fourth largest city in the state of North Carolina after Charlotte, Raleigh and Greensboro[1], has dedicated efforts to improve the environment as population grows. Our client, the Durham City-County Sustainability Office, works with other local government departments and the community in Durham to ensure environmentally friendly and sustainable development in the City and County. In 2007, the Sustainability Office adopted Durham's Greenhouse Gas Emissions Reduction Plan initiated by ICLEI, and the Office hired a Sustainability Manager in 2008, who is our direct client contact person, to help implement the plan and achieve the ambitious goals for reducing greenhouse gas emissions. Six years after the 2007 plan, we assisted the client to evaluate how the plan was implemented and what progress have been made for different projects based on the previous Durham GHG inventory results and the new re-inventory methodology provided by ICLEI.

a. Introduction of ICLEI

The Cities for Climate Protection Program (CCP) is a transnational municipal-level network aimed to reduce greenhouse gas emissions in cities around the world. Durham, as a member of the CCP, is committed to reduce greenhouse gas emissions from the community and the local government. The ICLEI Energy Services Division was brought in to help Durham develop a greenhouse gas inventory for the City and County level and create different action plan scenarios based on target levels of reduction. The established metric was to use 2005 as the baseline level and a 50% emissions reduction goal by 2030 from the baseline for local government sources.

[1] According to the 2012 U.S. Census Estimate of Municipality Population

b. 2007 ICLEI GHG Report

According to the Durham GHG Inventory and Local Action Plan (ICLEI, 2007b), the greenhouse gas (GHG) emission sources of the City of Durham and Durham Country are categorized into six sectors: buildings, vehicle fleets, streetlights & traffic signals, water & wastewater treatment facilities, waste produced through municipal operations, and public schools. Table 1 summarizes the energy cost, Criteria Air Pollutants (CAP) emissions, and GHG generated from the Durham city and county governments.

Table 1 Local Government Operations Emissions in Fiscal Year 2005 (ICLEI, 2007b)

Operations	**Total Energy (MMBtu)**	**Cost ($)**	**Emissions (tons)**					
			NOx	**SOx**	**CO**	**VOC**	**PM_{10}**	**GHGs**
Buildings	305,450	3,421,420	71	186	8	1	4	42,740
Vehicle Fleet	178,920	2,055,100	60	3	316	33	2	15,310
Streetlights	49,240	1,778,130	18	59	1	0	1	10,610
Water/ Sewage	163,670	2,381,080	58	182	4	1	4	33,560
Waste	0	3,310	N/A	N/A	N/A	N/A	N/A	-5
Schools	395,460	6,607,480	132	244	76	8	7	56,510
Total	**1,092,740**	**$16,246,510**	**339**	**673**	**405**	**43**	**18**	**158,710**

Buildings

The emissions of local government building sector (not including school buildings) was approximately 42,740 tons in 2005, which is 27% of the total emissions. Actions conducted to reduce energy consumption before 2005 led to savings of approximately 3,000 tons of GHG through efforts such as retrofitting county owned HVAC system and lighting (ICLEI, 2007b). Through data analysis, ICLEI suggested that the government should prioritize energy efficiency in the early stages of the building design process, such as purchasing renewable energy tags to offset emissions, using solar thermal technology for hot water heating in their facilities, and developing more water and energy conservation programs. In addition, ICLEI also identified the top five most energy intensive (energy use/square foot) buildings for both Durham County and the City of Durham. However, less than 25% of the City owned and operated facilities' data were available to ICLEI at that time, so the energy efficiency of more than 75% of the City's buildings was not calculated (ICLEI, 2007c). Therefore, ICLEI also recommended the City of Durham to access the square footage of all its facilities.

Vehicles

Vehicle fleets operated by the County and City include public works, fire department, police department, solid waste transportation, and public health department. The Durham GHG Inventory and Local Action Plan does not contain off-road engines such as lawnmowers and golf carts due to the difficulties in tracking their fuel consumptions and emissions. In 2005, there were approximately 1,195 fleet vehicles - consuming about 771,210 gallons of gasoline and 407,230 gallons of diesel fuel - operated by City and 360 vehicles - consuming about 235,240 gallons of gasoline and 23,140 gallons of diesel - operated by County (ICLEI, 2007b). Table 2 shows the detailed CAP and GHG emissions which accounted for 10% of the total local government GHG emissions.

Table 2 Local Government Vehicle Fleets: 2005 Energy Consumption, Costs and Emissions (ICLEI, 2007b)

Jurisdiction	**Energy (MMBtu)**	**Cost ($)**	**Emissions (tons)**					
			NOx	**SOx**	**CO**	**VOC**	**PM_{10}**	**GHGs**
City of Durham	146,560	1,687,880	52	2	242	25	2	12,540
Durham County	32,370	367,220	8	0	74	8	0	2,770
Total	**178,930**	**2,055,100**	**60**	**2**	**316**	**33**	**2**	**15,310**

The fuel-saving measures implemented before 2005 saved around 243 tons of GHG and have ample room for improvement. Moreover, the City of Durham was conducting an ongoing under-utilized vehicle study at that time. In order to further reduce emissions, ICLEI recommended governments adopt a tangible fuel reduction target (learning from Raleigh and the State of NC) by developing driver training programs and employing high energy efficient fuels and vehicles like biodiesels (ICLEI, 2007c).

Streetlights, Traffic Signals & Other Outdoor Lights

The lighting sector includes street and park lighting, accent lighting, and traffic signals operated by the City and County governments. These lights account for 10,610 tons of GHG emissions, equivalent to 7% of total local government emissions (ICLEI, 2007d). The City of Durham operates all of the traffic signals located within Durham County, and leases streetlights from Duke Energy and Piedmont EMC. In fiscal year 2005, 350 intersections with traffic signals were operated by the City. It was estimated that the city's traffic signals consumed 3,493,370 kWh of electricity in 2005 (ICLEI, 2007b). Some parking lot lights in the County were not captured in the light section and lights connected to County buildings were included in the building section. The recommendations for lighting by ICLEI include replacing mercury vapor street lighting with HPS street lighting and incandescent traffic signals with LED traffic signals. In addition, a remote streetlight control program is suggested to increase energy efficiency. Table 3 shows the detailed CAP emissions, energy use, and cost for lighting operations.

Table 3 Streetlights, Traffic Signals & Other Outdoor Lights: 2005 Energy Use, Cost, and Emissions (ICLEI, 2007b)

Lighting Type	Energy (MMBtu)	Cost ($)	Emissions (tons)					
			NOx	SOx	CO	VOC	PM_{10}	GHGs
Traffic Signals	11,920	267,140	4	14	0	0	0	2,570
Streetlights & other Outdoor lights	37,320	1,510,980	14	44	1	0	1	8,040
Total	**49,240**	**1,778,120**	**18**	**59**	**1**	**0**	**1**	**10,610**

Water and Wastewater Treatment

Two water treatment facilities and two water reclamation facilities are operated by the City of Durham. The treatment facilities have a total capacity of 52 million gallons per day (MGD) and the reclamation facilities have a total capacity of 40 MGD. The County operates a single wastewater treatment facility with a capacity of 12 MGD. In fiscal year 2005, the average output at the City's water treatment facilities was 26.44 MGD and 19.8 MGD at the wastewater reclamation facilities. The greenhouse gas emissions were 1.2 tons per MGD water treated and 2.4 tons per MGD of wastewater treated. Table 4 summarizes the total energy use, energy costs and GHG emissions (ICLEI, 2007b).

Table 4 Water and wastewater treatment facilities energy use (ICLEI, 2007b)

Jurisdiction	Area of Operations	Energy (MMBtu)	Energy Costs ($)	Emissions (tons)					
				NOx	SOx	CO	VOC	PM_{10}	GHGs
City	Water & Wastewater	1,41,870	19,92,510	50	156	3	1	3	28,860
County	Wastewater	21,800	3,88,560	8	26	1	0	1	4,700
Total		**1,63,670**	**23,81,080**	**58**	**182**	**4**	**1**	**4**	**33,560**

Solid Waste Produced by Local Government Operations

The emissions from solid waste generated by operations of local governments are included in the Local Government Waste Sector. It includes all employee generated waste and waste from municipal government facilities. Since emissions from city government operations are usually less than 3%, the common practice is for the City of Durham to not track its solid waste. The County's solid waste production for the fiscal year 2005 was 120 tons and 54 tons of GHGs were produced from decomposition in the landfill. Because methane was flared off, this reduced GHG emissions by 4 tons (ICLEI, 2007b).

Public Schools

At the request of Durham Advisory Committee, public school emissions were included in the local government sector of the 2007 report since the City and County of Durham have a significant degree of influence over the Durham Public Schools (DPS). DPS operate 51 buildings, including 46 schools and other operations and administrative facilities. DPS operations emitted 56,510 tons of GHG, accounting to 35% of all local government emissions. Based on the 2005 data, these DPS facilities consumed 312,850 MMBtu of energy (ICLEI, 2007e). The DPS vehicle fleet includes 332 school buses, 37 large trucks, 176 vans, and other small trucks and cars. The fleet used 125,000 gallons of unleaded gasoline and 552,830 gallons of biodiesel in the 2005 school year. ICLEI recommended building efficiency, fleet efficiency, and water and energy conservation education programs as future improvements (ICLEI, 2007f).

c. Report on Measuring and Reporting Progress

The Milestone 5 Guidance: Measuring and Reporting Progress in Emissions Reduction, published by ICLEI in January 2013, introduced methods of conducting GHG emissions re-inventory and reductions measurement (i.e., to monitor and report progress of previous climate actions plan). This is the Milestone 5 in ICLEI's Five Milestones for Climate Mitigation which was put forward before (see Figure 1). As pointed out, "it is important to develop systems and processes to monitor implementation, measure results over time, track changing conditions, leverage new information and ideas, and revise targets and plans as needed", in order to "ensure that climate action plans are implemented effectively and on schedule" (ICLEI, 2013).

Figure 1 ICLEI's Five Milestones for Climate Mitigation (ICLEI, 2013)

According to the Milestone 5 Guidance, there are two basic ways to track process of GHG emissions reduction: one is to show aggregate amount of emissions reduction compared to baseline inventory, and the other is to collect separate data from different individual projects under action plan and then to sum them up. ICLEI recommends the local governments to apply both methods when reviewing their climate actions plan, and provides detailed instructions of the measurements. Furthermore, in the section of Evaluating Emissions Reductions from Individual Projects, the methods are illustrated to specific categories: building energy, vehicle-related energy, community programs, and waste management. The Guidance also summarized the factors that need to be considered for calculating emissions, including project-related factors (see Table 5) and external factors, such as, population in the city, weather, economic growth, etc. Furthermore, Milestone 5 provides a framework on how to use above information to re-evaluate the existing Climate Action Plan and the emissions reduction goals.

Table 5 Factors Affecting Emissions (ICLEI, 2013)

	1. GHG Re-Inventory (primary importance to track)		**2. Factors Affecting Activity Data (secondary importance)**	
Emissions Source	Activity Data Monitored	Emissions Factors	Local Action Metrics	External Factors
Electricity	- kWh consumed	- CO_2 emissions per kWh	- Energy efficiency projects - New distributed energy generation (solar)	- Cooling Degree Days (for A/C use) - Population growth - Jobs growth - Economic Growth
Natural Gas	- Therms consumed	- CO_2 emissions per therm (constant)	- Energy efficiency projects	- Heating Degree Days (for heating use) - Population growth - Jobs growth - Economic Growth
Transportation	- Vehicle Miles Traveled	- CO_2 emissions per mile	- Changes in mode share (if available) - Public transportation ridership rates	- Population growth - Jobs growth - Economic Growth
Waste	- Tons of waste generated	- CO_2e per ton of waste landfilled (depends on capture technology at landfill)	- Diversion rate	- Population growth - Jobs growth - Economic Growth

4. Methodology

Our research followed a series of steps: literature review on greenhouse gas reduction plans and calculation methods, in-depth interviews, comparative analysis, and recommendation. The scope of this study included the local government of Durham City and County. The emissions of the local governments were quantified from buildings, vehicle fleets, streetlights and traffic signals, water and wastewater treatment facilities, and wastes, different from the 2007 ICLEI report which includes the analysis of public schools in community. Given limited data, energy use intensity was calculated for each building, and was averaged in each fiscal year[2]. In an effort to obtain background information about any operational changes such as building operation hours and light bulb standards, a preliminary list of questions was sent by email to the client, i.e. the Durham Sustainability Office and other relevant government offices. Their responses as well as further in-person meetings helped us obtain a general overview of greenhouse gas reduction projects implemented by different departments such as the General Services Department of Durham City and County, Water Management of City, Fire Stations, and so forth.

Upon completion of the background study of each project under different departments, the data collection process followed. In order to obtain as much detailed and relevant data as possible, the data collection process required in-depth interviews involving emails and phone exchanges with staff and officials who were in charge of the projects. For example, the staff in the Department of Transportation who worked with ICLEI in 2007 were contacted to identify any changes in regulation and operations in addition to the number of vehicles the government owns at present.

The primary data sources were from the General Services Department of Durham County, Durham City Water Department, Fire Stations, the Department of Transportation, Duke Energy, and PSNC Energy. The data acquired includes mainly energy consumption including gas and electricity and costs of each upgrade project. The collected data is listed below in detail. (Refer to Appendix 1 and 2 for a list of Durham City and County buildings.)

[2] From this section, our analysis is mainly based on fiscal year (FY). For example, as for FY 2010, it starts from July 2009 to June 2010. If not indicated with FY, then it goes with regular year which is from January to December.

Table 6 A list of Data Collected from Each Sector

Sector	Source	Data Provided
Vehicle Fleets	DATA Bus Planner and Fleet Coordinator, Durham County Government	Vehicle miles traveled, fuel uses and costs
Water and Wastewater	Senior Engineer, Durham City Water Department.	Two treatment plants' energy consumption, GHG emission data, data of two wastewater reclamation facilities for the City and one wastewater treatment plant for the County
Buildings	Sustainability Manager, Durham City-County Sustainability Office Utility Division Manager, Durham County Government	A list of buildings, energy cost (natural gas bills and electricity bills), energy consumption, square footage information for City and County buildings
Street lights, Traffic signals, and Other outdoor Lights	Traffic System Supervisor, Durham Department of Transportation.	Energy consumption, energy cost, GHG emissions, lighting upgrades costs

Due to the missing or unavailable data, we calculated change in efficiency or intensity instead of calculating the reduced energy consumption or greenhouse gas emissions for some projects. For example, data about the entire city and county buildings including square footage information and energy usage was not available. Thus, building energy use intensity was calculated based on the existing list of buildings. In addition, data about vehicle fleets and wastewater treatment plants was only available for a couple of years. We stated clearly in each project about the missing data so that the interpretation and inference is not misleading. For example, the energy use intensity dramatically dropped in fiscal year 2010, and this is actually due to the missing natural gas data of Durham County buildings.

As for the emissions factors, we used the data from eGrid and U.S. Energy Information Administration (EIA). The average grid electricity coefficients were provided by our client who retrieved the numbers from CACP (Clean Air Climate Protection) model, the software used by ICLEI to calculate GHG emissions. In fact, these numbers (see Table 7) are from eGrid (Sustainability Manager, 2014b). The CO_2 equivalent emissions we used in transportation for one gallon of gasoline is 0.00884 tons, and for one gallon of diesel is 0.01119 tons which were retrieved from EIA (EIA, 2013).

Table 7 Average Grid Electricity Coefficients from 2006 to 2013 (Sustainability Manager, 2014b)

	2006	2007	2008	2009	2010	2011	2012	2013
CO_2 Tons/GWh	728.6	723.2	719.6	714.6	708.7	705.5	701	697.9

Following the methods provided by Milestone 5 Guidance, the data analysis relies on several basic calculations. For example, the energy usage of any piece of equipment that uses electricity is to multiply the power load (usually measured in watts or Btu/hr) by the time the equipment is on. Other equations are shown in the table below:

Table 8 Basic Data Calculation Equations

	Equations
Electricity Use (kWh)	Power input (watts) × time on (hrs/year)
GHG Emissions of Electricity (ton)	Electricity use (kWh) × emission factor (CO_2e/kWh)
Fuel Use (gallon)	Driving distance (miles) ÷ mileage (mpg)
GHG Emissions of Fuel (ton)	Fuel use (gallon) × emission factor (CO_2e/gallon)

Finally, recommendations are provided based on the data analysis, which highlights the priorities for the Durham government's future GHG emissions reduction plan.

5. Project-Based Analysis and Results

The focus of our project is government-level greenhouse gas emissions. This includes the county and city related services such as transportation, buildings, waste treatment, and waste management, but does not include schools and community usage. Because our primary method of data collection is through interviews, we were able to get initial feedback on the type of projects that have occurred in each department. Based on the types of projects, we collected relevant quantitative information through our interviews with contacts and supplemented it with past data from the Durham Sustainability Office. When current project data was not available, we used the most up to date data from Durham Sustainability Office for analysis.

Our reporting structure follows a similar layout to the ICLEI greenhouse plan to provide consistent information transfer. For each section, we analyzed the results from the qualitative and quantitative information we collected from city and county departments. Depending on the type of data, we examined the trend of energy use and greenhouse gas emissions through time and common metrics used to measure energy intensity. Combining information from the interviews and collected data, we analyzed the effectiveness of projects and recommended further actions for the departments to take.

a. Buildings Upgrade Project

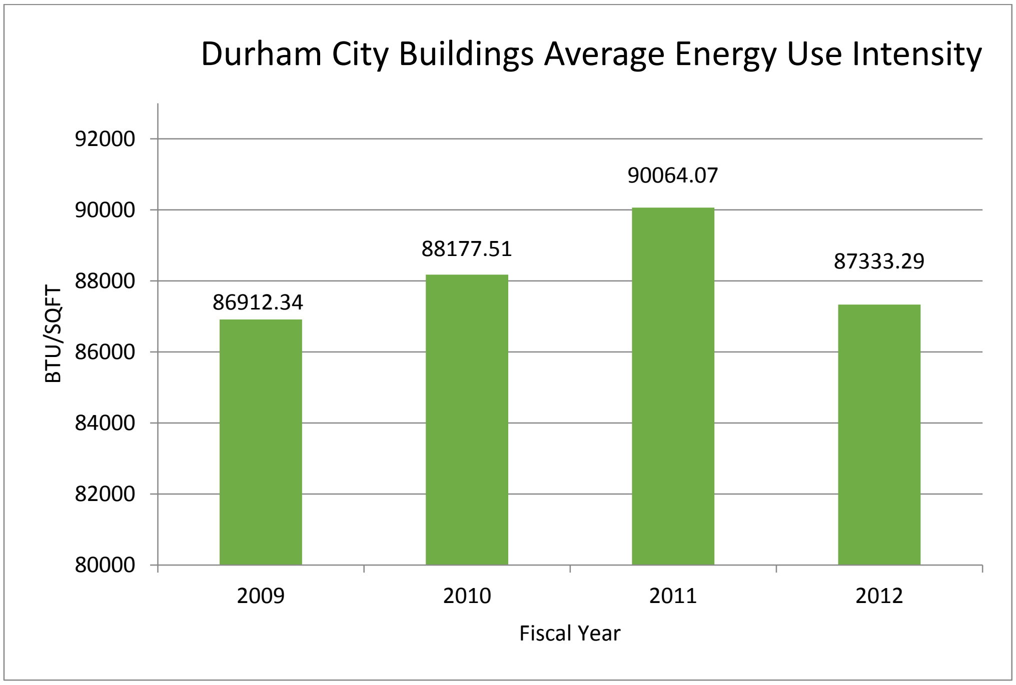
We examined Durham City and County building upgrade projects that have occurred since fiscal year (FY) 2006. For Durham County, we examined energy usage of 37-42 buildings from fiscal year 2006 to fiscal year 2012. Average energy use intensity was calculated for the entire fiscal year; however, to examine recent change in electricity usage for the analysis, we examined 41 buildings from fiscal year 2010 to 2011, and 42 buildings from fiscal year 2012 to 2013. Buildings include administrative buildings such as health department, general services complex, administrative complex, detention center, judicial buildings, and etc. (see Appendix 2). For Durham city, we examined energy usage of 57 buildings from fiscal year 2009 to fiscal year 2012. Each year, there were new buildings, but we excluded them in the analysis for the purpose of comparison and due to missing data for those new buildings.

The imperfect data set or unavailable data made it difficult to compare performance between fiscal years. Therefore, our analysis heavily relies on Energy Use Intensity (EUI), which is calculated by BTU per square footage. Further analysis was not possible due to the lack of specific information on buildings such as individual building upgrade project, a different usage of the buildings, and the number of employees.

Durham City Buildings

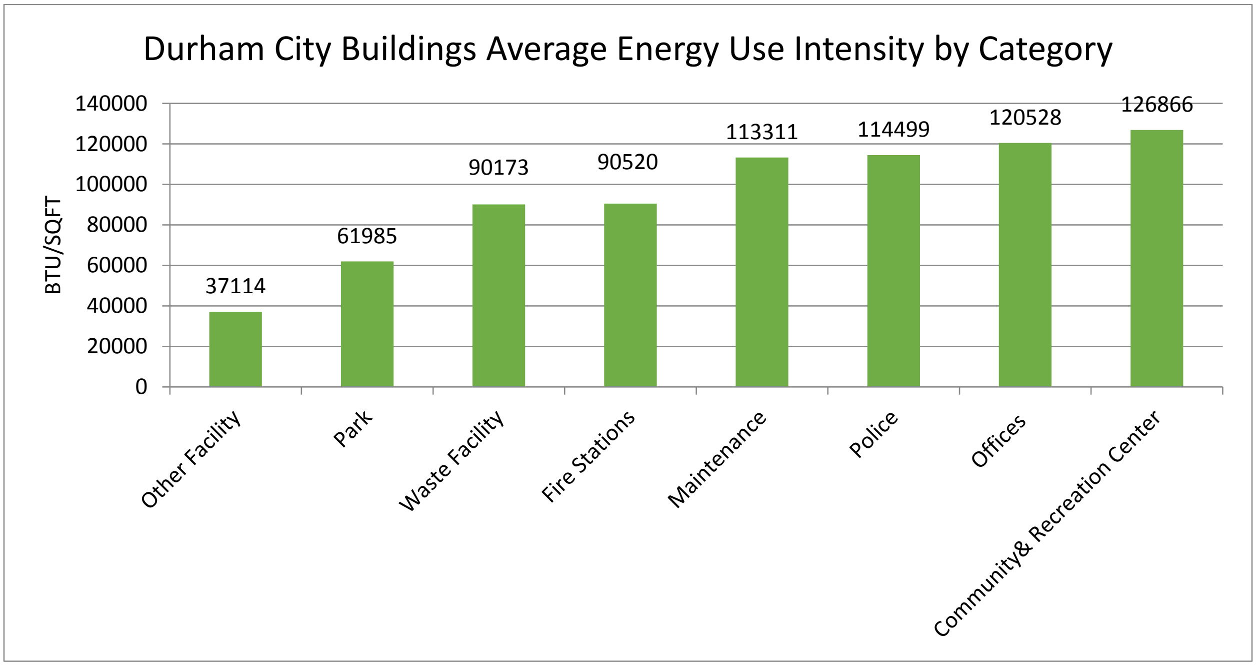
Based on energy consumption data and square footage information of all buildings, energy use intensity of city buildings was calculated and averaged in each year. Durham city implemented boiler upgrades, energy efficiency appliance upgrades, and lighting upgrades. Figure 2 shows the increasing trend of the average energy use intensity for city buildings from fiscal year 2009 to 2011 and it dropped significantly in fiscal year 2012. It is speculated that those upgrade projects had a positive impact on reducing energy consumption.

Figure 2 Durham City Buildings Average Energy Use Intensity from FY 2009 to 2012



In order to evaluate which buildings have the highest energy use intensity, city buildings were classified into eight different categories such as administrative offices, fire stations, recreation & community center, maintenance building, and so on. Figure 3 demonstrates that community and recreation centers have the highest average energy use intensity for the period followed by administrative offices and police buildings. We speculate that this is because of the number of people who use the buildings and their behavior. Further information about change in the number of employees and user behavior in those buildings is necessary. Prioritizing those three categories for identifying future energy saving opportunities would be a promising option.

Figure 3 Durham City Buildings Average Energy Use Intensity by Category from FY 2009 to 2012



– Case study: Fire Stations

We interviewed a Maintenance Technician from fire stations. There are a total of 16 stations. Most upgrade projects related to energy savings were implemented in 2010 and 2011. Government grants enabled fire stations to purchase energy efficient appliances, which include 60 refrigerators and 16-18 water efficient washing machines. About 890 Lights were replaced in ten stations because six stations had already changed lights or some of stations were recently built. Lighting upgrade projects were implemented in 2012. Incandescent bulbs in those ten stations were changed to PL or LED. T12 Fluorescent bulbs were changed to T8 Fluorescent bulbs. 150 Exit sign was replaced to LED. These lighting upgrades are going to be expanded for exterior lights and parking lot lightings in the future (Maintenance Technician, 2013).

A noticeable upgrade is the solar pre-heat system for hot water, which was installed in five stations. This demonstrated cost saving considering that fire stations use a lot of natural gas for hot water. Thus, this system is considered to be a standard in other stations. A new station under construction will be equipped with a solar hot water system, which will be occupied at the end of the year.

As a result of upgrades listed, the fire stations have seen progress in energy saving. As seen in Figure 4, energy use intensity for fire station No.2 to No.16 (metering for fire station No. 1 is not separated, and fire station No.15 was excluded due to missing data) has been decreased after fiscal year 2010 when most upgrades were implemented.

Figure 4 Durham Fire Stations Average Energy Use Intensity from FY 2009 to 2012

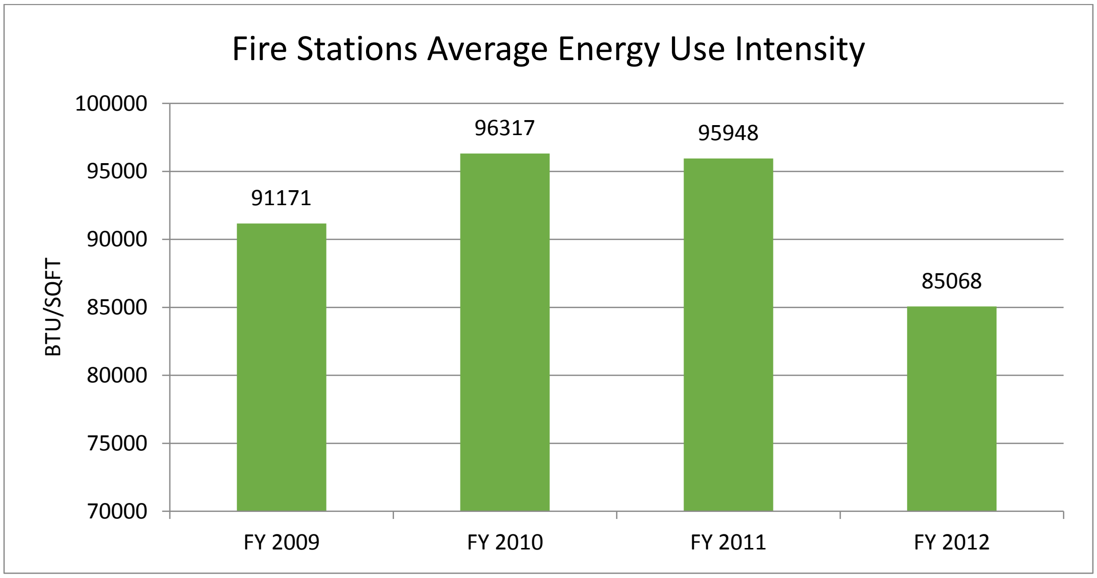


Figure 5 Fire Stations Electricity Energy Use (kWh) from FY 2009 to 2013

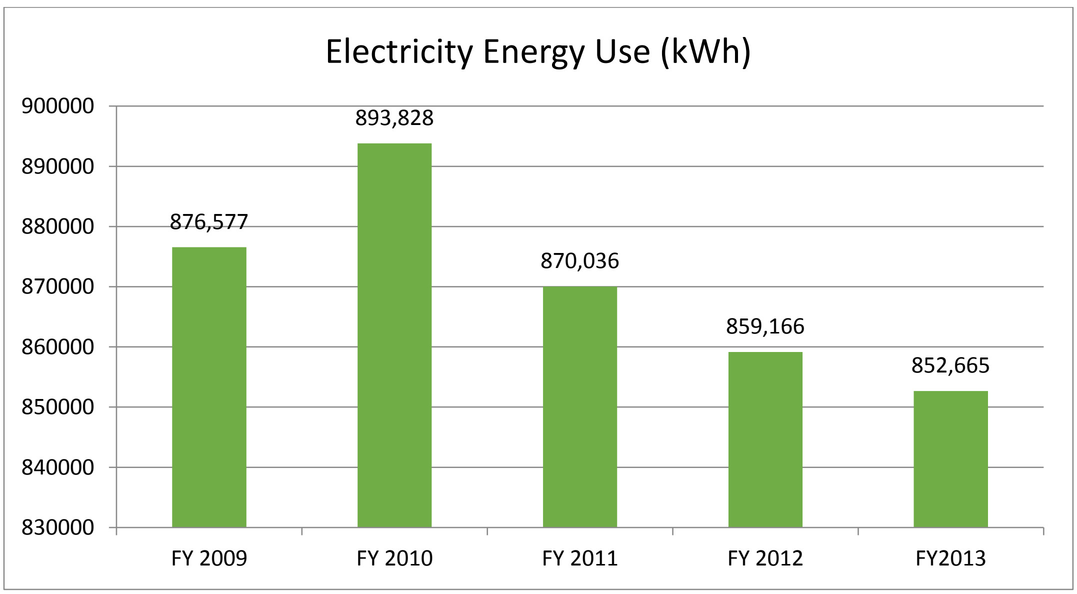


Figure 5 shows that electricity energy use in kWh has been decreasing since 2010. Natural gas data for fiscal year 2013 was unavailable to analyze changes. From the interview, we discovered that upper administrators at the fire stations were highly interested in future energy saving opportunities. The interviewee was asked by them to incorporate new ideas into future building maintenance that can conserve gas, water, and electricity consumption. This way of thinking for any repairs and upgrades in building maintenance is critical to start working in this direction. In order to do that, upper administrator's leadership as well as communication with facility mangers is the key to implement energy saving projects.

However, the fire stations have observed various limitations. The main obstacle to implement energy saving initiatives was finite financial resources. As a municipal government, allocating large amount of financial resources in energy saving projects is difficult. Without federal government funding, no projects including boiler replacement and HVAC controls upgrades could have been implemented in fire stations. Although the solar hot water system has the benefit of 6 to 7 months of reduction of the bill amount in a year, the payback period is long due to high upfront cost. Nevertheless, energy saving initiatives will help the fire station to reduce energy costs in the long run according to the interviewee.

As for future upgrades, the fire stations are working with City government for building new stations and a fire garage in the summer of 2014. Heat and air upgrade systems in two locations are in the process of being planned. In addition, occupancy sensors, insulation, more LED, and solar options for lighting are being considered. The fire stations department has begun to request funding for further interior and exterior fixtures and some occupancy sensors.

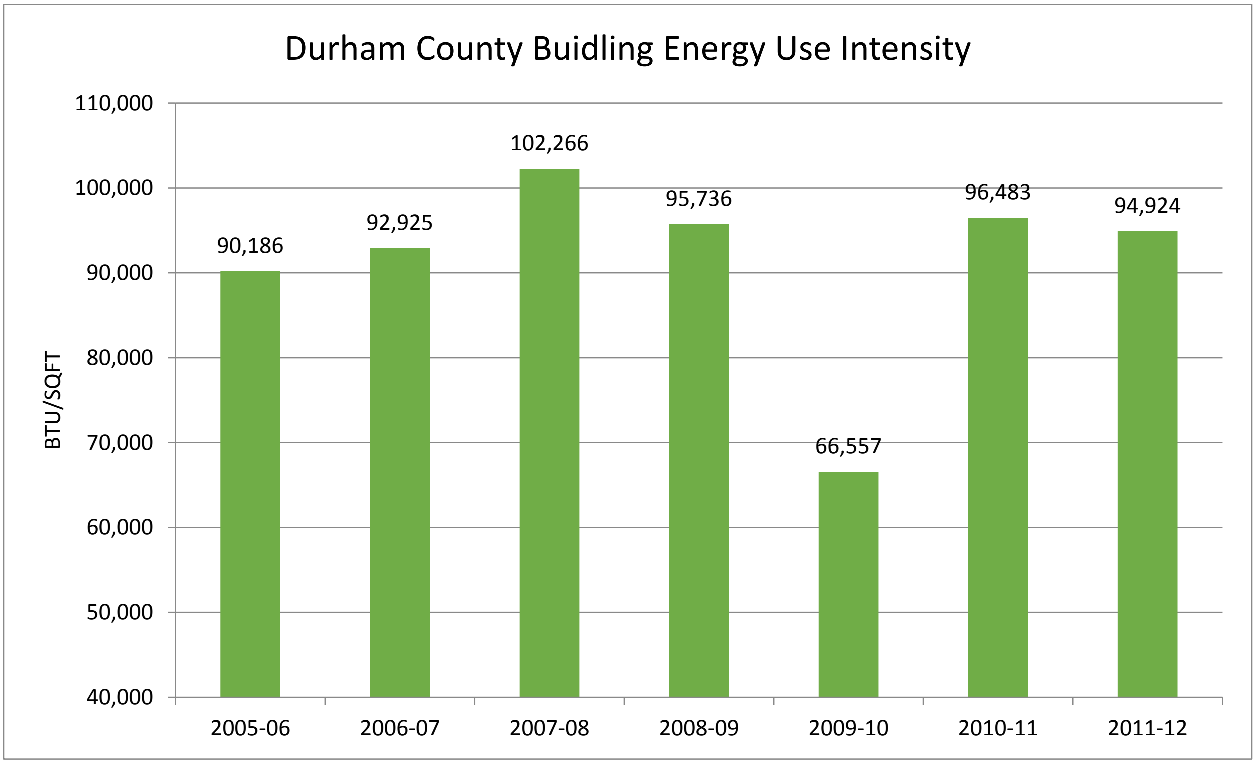
We recommend consolidating documentation on energy projects to evaluate project benefits. Because fire stations did not have an established procedure to document projects, they could not evaluate energy savings in detail. To scale up, Durham fire stations with a couple of other local fire departments are trying to encourage fire departments across the country to implement similar energy saving initiatives. They also try to foster a closer relationship with Emergency Medical Services to encourage them to start energy saving initiatives.

Durham County Buildings

Figure 6 demonstrates the average Durham County building energy intensity from FY 2006 to 2012. The county buildings had lighting upgrades and performance contracting to replace boilers and water systems. Specific data for the date of all the upgrades is not available. A list of county buildings by category is stated in Appendix 2.

As Figure 6 shows, EUI for county buildings has been gradually decreasing since peaking in 2007. The reason why EUI is low in fiscal year 2010 is presumably because natural gas usage data of some buildings such as General Services Complex building is missing.

Figure 6 Durham County Building Energy Use Intensity from FY 2006 to 2012



To evaluate which buildings have high energy use intensity, average building energy use intensity by sector is analyzed. Eight categories include Administrative Offices, Emergency Medical Services, Recreation, Administrative offices, Libraries, Detention Facilities, Judicial buildings, Sheriff, and Other facilities (animal shelter, community shelter, and operation breakthrough). As Figure 7 shows, judicial buildings followed by detention facilities and other facilities have the highest average energy intensity for the period.

Figure 7 Average Energy Use Intensity (BTU/sqft) from FY 2006 to 2012

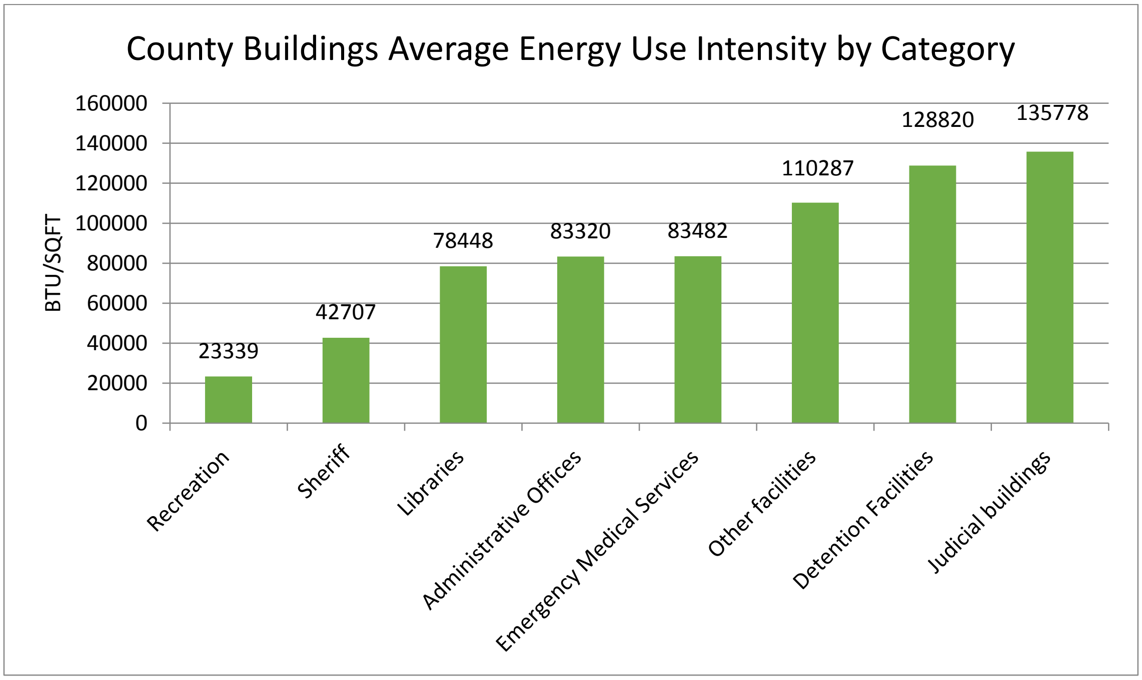


Figure 8 Durham County Buildings Electricity Use (kWh) from FY 2010 to 2013

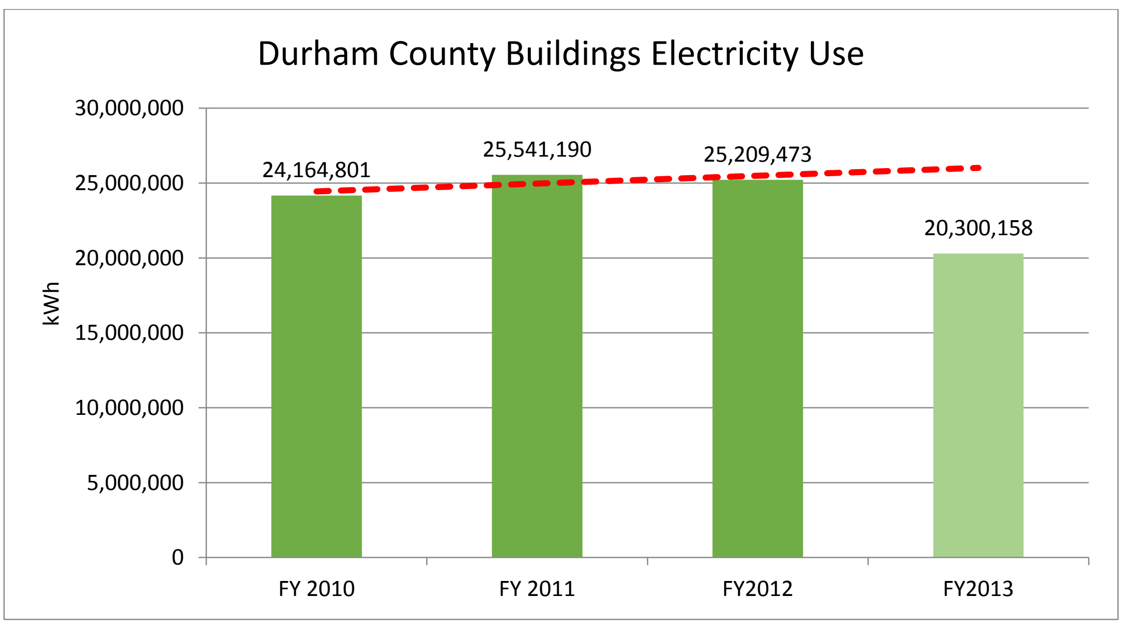


Figure 8 shows the change in electricity energy use in kWh for Durham County buildings for four fiscal years. It was expected to increase by following a linear trend line; but the electricity use dropped in fiscal year 2013. There might be various explanations for the decrease, however, we speculate that this is a result of energy saving efforts by the sustainability office. The GHG reduction for Durham County buildings may be explained by a performance contract.

Durham County Government Performance Contract

Durham County Government outsourced several energy upgrade projects in seven buildings. Lighting upgrades, water retrofits, roof top unit replacements, and HVAC controls were the major projects conducted. The projects specifically include lighting retrofits from T12 to T8K, LED exit signs, new air handling units at operation breakthrough, building controls at all the buildings, and the Durham County Detention Facility upgrades such as water saving toilets, new chiller and boiler installation, and new air handling units.

The interim report by an energy service company, Trane estimated energy saving up to $200,000 for the period of July 2012 to mid-November, 2013 (Trane US, Inc., 2013). The energy and water savings were measured using three different methods, which are the Point Source Partially Measured Retrofit Isolation method (lighting upgrades, water retrofits, and roof top unit replacements), the Point Source Measured Retrofit Isolation method (HVAC controls), and the Continuous Metering method (All EMCs in the Detention center). As seen Table 9, the estimated energy savings by lighting upgrades was $4,979 from September 27, 2012 through December 31, 2013. This accounts for 2.25% of the total saving. The estimated savings of HVAC controls accounts for 2.95% of the total saving ($6,547). Water upgrades were estimated to save $23,159, which is equivalent to 2.16 billion gallons of water, accounting for about 10% of the total. For the detention center upgrades, the facility has been continuously metered. The estimated saving is the highest, $186,882 from January, 2012 through October, 2013. This saving was calculated by total utility dollars based on historic utility bill patterns and corrected for the contracted rate (Trane US, Inc., 2013).

Table 9 Durham County Performance Contract

Projects	Savings (Dollars)
Lighting upgrades	$4,979
HVAC Controls	$6,547
Water Upgrades	$23,159
RTU Replacement	$65
Continuous metering in the Detention Center	$186,882
Totals	$221,631

b. Transportation Projects

Based on current data, we have up to date information on County Fleet Vehicles from fiscal year (FY) 2011 to 2013, DATA Bus data from FY 2011 to 2012, and Light Duty Vehicle data from FY 2012. Due to the difference in the number of vehicles and how accurately their usage was tracked, slightly different methods of analysis were used to calculate their efficiency in miles per gallon and their potential greenhouse gas reduction.

Government Vehicle Fleet

Government vehicles produce a significant amount of direct greenhouse gas emissions. With the rising popularity of hybrid and electric vehicles, we wanted to determine what types of projects the Durham government has put in place to address vehicle emissions. We also wanted to determine the effectiveness of implementing more hybrid or electric vehicles into the fleet based on driving patterns and maintenance cost.

— **City Vehicle Fleet**

The supervisor, who is in charge of fleet upgrades in the city government, provided details on fleet composition in Durham government. With more than 700 gasoline vehicles and around 300 diesel vehicles, mainly trucks, the government is now moving toward buying more hybrid vehicles (Fleet Supervisor, 2013). Since 2005, the government acquired four hybrid vehicles, mostly Ford Fusion with 22 mpg, and four electric vehicles with 49 mpg. These vehicles are assigned to specific individuals or groups of eight different departments, including police, water management, and etc. Some vehicles drive on a daily basis; others depend on situations. Those vehicles usually have 1 to 2 people sitting inside for the most of the time.

In terms of fuel consumption, the contact person was unable to provide the data of all vehicles due to variation in the available data. Moreover, he was reluctant to share access to the existing management system, which collects the information of each vehicle, and he recommended using miles per gallon to calculate fuel consumption. However, more data is needed in order to calculate the fuel usage.

— **County Vehicle Fleet**

We were able to acquire the county vehicle data from the county fleet coordinator. The data included the year and model of all fleet vehicles, miles traveled, fuel type, fuel used, and cost of fuel in FY 2011 to 2013. We categorized vehicles by fuel type into gasoline and diesel vehicles. We further divided gasoline vehicles into different types, including passenger, SUV, truck, and van (Figure 10). Because diesel vehicles were all trucks, no further categories were necessary. The fleet's miles traveled has increased every year since 2011, but the breakdown by vehicle types show that passenger vehicles' miles traveled is the majority of all vehicle miles (Figure 11).

As for vehicle efficiency, all vehicle categories have stayed roughly the same, with slight efficiency losses in recent years. The more interesting aspect is that SUVs have a higher average mileage than all other vehicle type measured in miles per gallon (MPG) (Figure 9). Passenger vehicles are lower than the SUV average, but higher than the overall fleet averages. The lower MPG of passenger vehicles is attributed to a large fleet of Ford Crown Victoria and Dodge Charger models, which are mostly used by the police department. The MPG being lower than the suggested MPG of each model could be due to the driving patterns of police vehicles. Currently, the county fleet only has one hybrid vehicle, which is a 2012 Ford Fusion. It has the highest average MPG of any vehicle in the fleet. Using hybrids or more efficient gasoline vehicles can improve the overall fleet efficiency and reduce total gas consumption. The police department should look into hybrid vehicles for upgrades due to potential fuel reduction from their driving behavior. Diesel vehicle miles climbed around 15% every year from 2011- 2013, but the average MPG is consistently around 6.7 MPG. Hybrid diesel trucks are not as developed compared to passenger vehicles, so we suggest looking into hybrid vehicles in the future.

Figure 9 County Fleet Vehicle Efficiency by Type

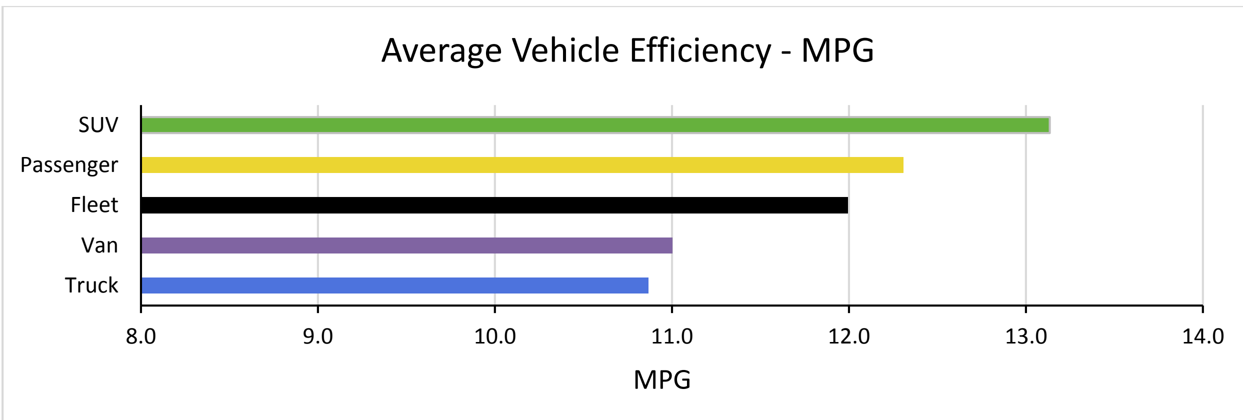


Figure 11 County Fleet Vehicle Type Breakdown

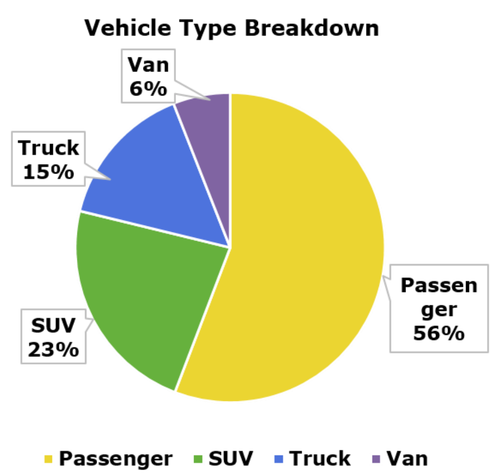
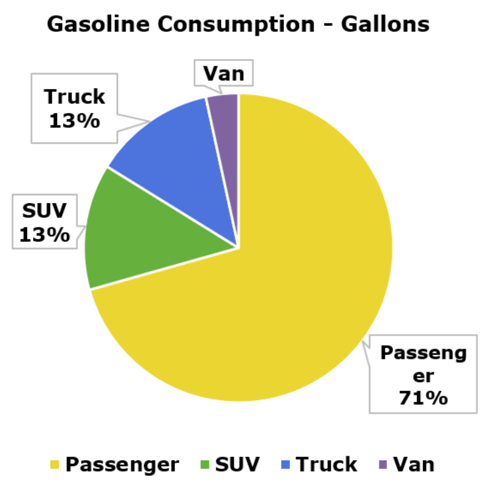


Figure 10 County Fleet Vehicle Gasoline Consumption



Public Transportation Project

As the city grows, demand for public transportation also increases. Durham County has its own bus system called the Durham Area Transit Authority (DATA), and it has worked with the Triangle Transit to make public transportation more available and accessible for travel between cities. Our focus is on the public transportation of the DATA system and light duty vehicle (LTV) transportation used by the Durham City and County. We analyzed the efficiency of hybrid diesel vehicles compared to diesel vehicles for use in public transportation, and suggest that Durham use more hybrid vehicles.

— DATA Bus System

In our interview with the DATA Bus Transportation Planner, we were able to gain further insight into the performance of higher efficiency vehicles. Since 2009, there has been a phased implementation of 25 hybrid buses for the city of Durham, 10 for replacement of current buses and 15 for expansion. Majority of the funds were from the federal government, with the remaining cost evenly distributed by the state and local government (DATA Planner, 2013). In addition to hybrid buses, 10 hybrid light transit vehicles (LTV) were also purchased along with 22 gas powered LTVs. The LTV was partially funded by the Durham Sustainability Office from the sustainability fund. Feedback from the interviewee for the hybrid buses was generally positive. Hybrid buses have higher savings in city traffic, and reliability has been positive, but currently the high cost of battery replacement might make it a difficult decision whether to replace batteries or convert to normal diesel. Hybrid LTV has not been reliable and due to the bankruptcy of the manufacturer, vehicle support no longer exists. The current plan is to convert the hybrid LTV to normal gas powered vehicles, and there are similar plans for the vans.

The high cost of maintenance and battery replacement is a major barrier to the success of these hybrid vehicles. Further financial analysis will be needed to determine if the battery cost can be covered through improved efficiency. In the future, Durham transportation is looking into hybrid buses as well as compressed natural gas (CNG) development for vehicles.

Between FY 2011 and 2012, one 2000 Gillig and three 2001 Gillig were taken offline, and therefore their fuel and travel data were not included in 2012. All 2010 Gillig Hybrids were in operation in 2012, and additional five 2012 Gillig were added to the bus fleet. The hybrid buses were driven less on average, which was reflected in the average vehicle miles traveled (VMT). This is mostly due to the city routes they are assigned, whereas the non-hybrid buses also traveled highway routes on a regular basis. There is no significant difference in the efficiency improvement from the age of the non-hybrid buses, but there is a significant difference between hybrid and non-hybrid buses. Using the efficiency differences, the calculated CO_2 was compared between a 2008 Gillig driving the same distance as the average 2010 and 2012 Gillig Hybrid for the year 2012. We used an emission factor of 22.38 lb CO_2/gal diesel for as per EIA (EIA 2013). The 2012 Gillig Hybrid CO_2 reduction was less than the 2010 Gillig Hybrid model because of the lower vehicle miles traveled. However, because MPG is nonlinear, fuel savings at lower MPG can be significant, as shown in Table 10. The 2010 Gillig Hybrid can save over 3000 gallons of diesel per vehicle compared to a non-hybrid assuming the same vehicle miles traveled Further analysis is required to see long term performance of hybrid buses on highway routes to determine if the MPG reduction is still sustainable. This could determine if more hybrid buses will be used in the future. The 2008 Goshen vehicles have higher MPG because it is a light duty vehicle and is not considered a bus.

Table 10 DATA Bus Fuel, Mileage, mpg, CO_2e, and Fuel Reduction in FY 2011 and 2012

	FY 2011 TOTALS / AVERAGES				**FY 2012 TOTALS / AVERAGES**				**CO_2e Reduction (t/veh) (vs 2008 Gillig)**	**Fuel Reduction (gal/veh) (vs 2008 Gillig)**
	Fuel (Gal)	**Milage**	**MPG**	**AVG VMT**	**Fuel (Gal)**	**Mileage**	**MPG**	**AVG VMT**		
2000 Gillig	9,181	42,824	4.66	42,824						
2001 Gillig	10,636	48,509	4.56	24,254						
2003 Gillig	233,151	851,120	3.65	31,522	318,443	1,177,192	3.70	42,042		
2005 Gillig	5,669	18,928	3.34	18,928	13,821	46,253	3.35	46,253		
2008 Gillig	80,865	298,505	3.69	49,750	80,759	302,601	3.75	50,433		
2008 Goshen	24,221	201,421	8.32	40,284	18,793	167,221	8.90	3,758		
2010 Gillig Hybrid	259,207	1,346,650	5.20	67,332	228,090	1,084,217	4.75	54,210.85	34.28	3,064
2012 Gillig Hybrid					8,502	39,523	4.65	7,904.60	4.58	409

— Light Duty Vehicle

The light duty vehicle data included vehicles owned by the city and county. The data contained the individual models and the number of vehicles for each model, along with the total miles traveled, and total fuel used. We calculated the average efficiency of the different vehicle models by dividing the total miles traveled with the total fuel used. All of these vehicles use diesel as fuel source, and so we found the CO_2 reduction by comparing hybrid and non-hybrid models. E350 and the HIGHTOP model still retained their original form, and so they were significantly lighter than the CUTAWAY models, which were replaced with a larger load capacity. This difference can explain the energy efficiency differences between the two models. Our main comparisons are the E350, E450 CUTAWAY and hybrid models. The hybrid models were more efficient than the non-hybrid model, and provided comparable CO_2 reduction to the buses based on the miles traveled. However, from our communication with the DATA system planner, the E450 Hybrids broke down often and required higher maintenance, which made it not as attractive for additions to the fleet. Currently, hybrid LTVs are scheduled for conversion to normal diesel vehicles. If future hybrid LTVs are considered in the future, Durham should make sure that the manufacturer can provide long term support.

Table 11 Light Duty Vehicle (LTV) Fuel, Mileage, mpg, and CO_2e Reduction in FY 2011 and 2012

Summary	# of Vehicles	Total Miles Traveled	Total Fuel Used	Average MPG	AVG VMT	CO_2e Reduction (t/veh)	Fuel Reduction (gal/veh)
E-350	2	45,583	4,873	9.35	22,792		
E-350 CUTAWAY	7	290,840	39,140	7.43	41,549		
E-350 HIGHTOP	20	352,326	37,179	9.48	17,616		
E-450 CUTAWAY	15	650,616	95,459	6.82	43,374		
E-450 CUTAWAY HYBRID	10	213,543	25,912	8.24	21,354	21.33	2413

c. Traffic Signal Project

In order to ensure the safety on road, the traffic signals and streetlights play an important role in transportation. The traffic signals should function at all times and streetlights need to provide enough light at night, thus, they consume substantial energy.

The traffic signal and streetlight project conducted in Durham was intended to save electricity consumption. The interview with the Traffic System Supervisor from the Department of Transportation illustrated the situation of current traffic signals and street lights in Durham. According to the supervisor, there are totally 403 signals in Durham with 95% of them using LEDs. During the last five years, a huge push initiated in 2008 and 2009 was targeted at upgrading LEDs (2-4 amps per signal), and processing the old signal lights (12-15 amps per signal) for recycling (Traffic System Supervisor interview, 2013). The data for energy usage and utility bills of these traffic signals needed to be collected from North Carolina Department of Transportation (NCDOT), because out of the 403 signals in Durham, NCDOT owns around 330-340 signals and the rest belong to the city government (Traffic System Supervisor, 2013). But the city government is in charge of maintaining all the signals in Durham and the supervisor provided us some data of traffic signals after contacting NCDOT.

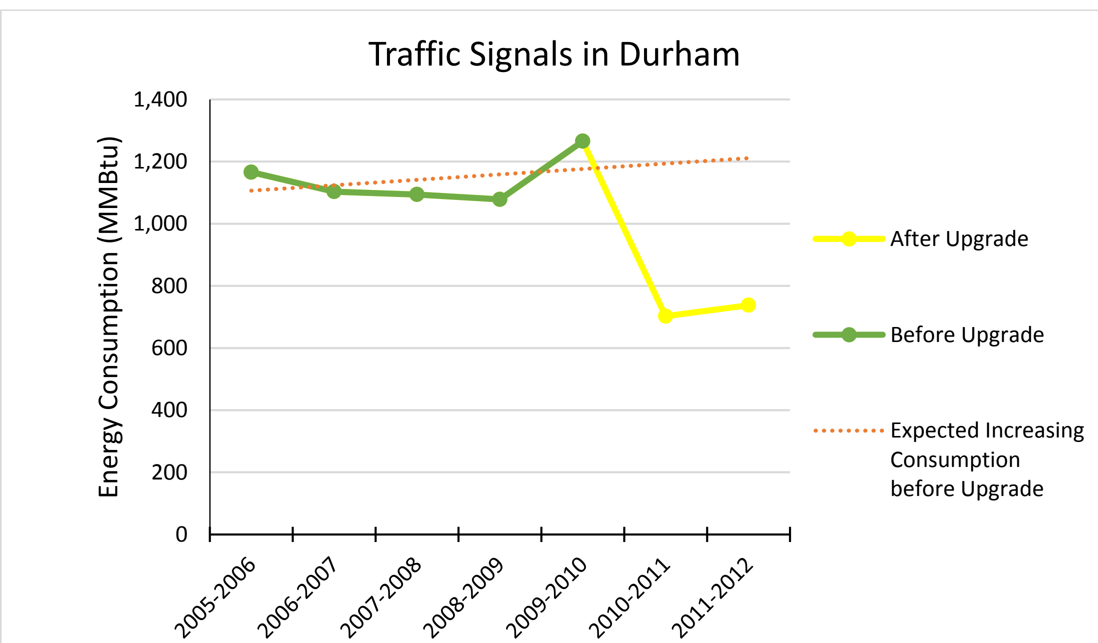
There was a special LED streetlight project for the rail track underpass bridge in Durham. Originally, there were unmetered high pressure sodium lights, most likely 250W lamps. Duke Energy later cut the power to these lights as they were not metered, and for two years there were no lights in that section (Traffic System Supervisor interview, 2013). With the LED streetlight project, the city government installed 46 individual LED light units in this area and started metering the lights. It would be interesting to compare the LED lighting project to similar high pressure sodium lights for their efficiencies. However, the energy consumption data of these specific streetlights were not available to us (Traffic System Supervisor interview, 2013).

Table 12 Traffic Signals: Energy Consumption and CO_2e Emission since FY 2006

Year	Quantity (kWh)	Energy (MMBtu)	CO2e Emission (tons)
2005-2006	341,659	1,166	250
2006-2007	323,344	1,103	235
2007-2008	320,615	1,094	232
2008-2009	316,024	1,078	227
2009-2010	370,886	1,265	264
2010-2011	205,822	702	146
2011-2012	216,156	738	152

Table 10 lists the energy consumption and CO_2 equivalent emissions of all the traffic signals in Durham from FY 2006 to 2012 (Sustainability Manager, 2014a). Using the energy consumption (whether in kWh or MMBtu) and CO_2e Emission, total emissions were obtained by multiplying the energy with the emission factor. As observed in Figure 12, there was a significant decrease of energy consumption after upgrading most of the traffic signals with LEDs around 2009. The dashed line indicates that if the traffic signals in Durham continue to use old light bulbs, the total energy consumption would increase steadily every year.[3] In fact, the energy consumption dropped drastically from 1000 MMBtu level to around 700 MMBtu level due to the savings from LED lights. As for the slightly increasing consumption from FY 2011 to FY 2012, the reason is that Durham kept installing more traffic signals on the roads so that the total number of traffic signals increased resulting in more energy usage.

Figure 12 Energy Consumption of Traffic Signals in Durham from FY 2006 to 2012



[3] The dash line was obtained by adding the trend line of energy consumption before upgrade in Excel which follows a linear regression.

d. Water Management Project

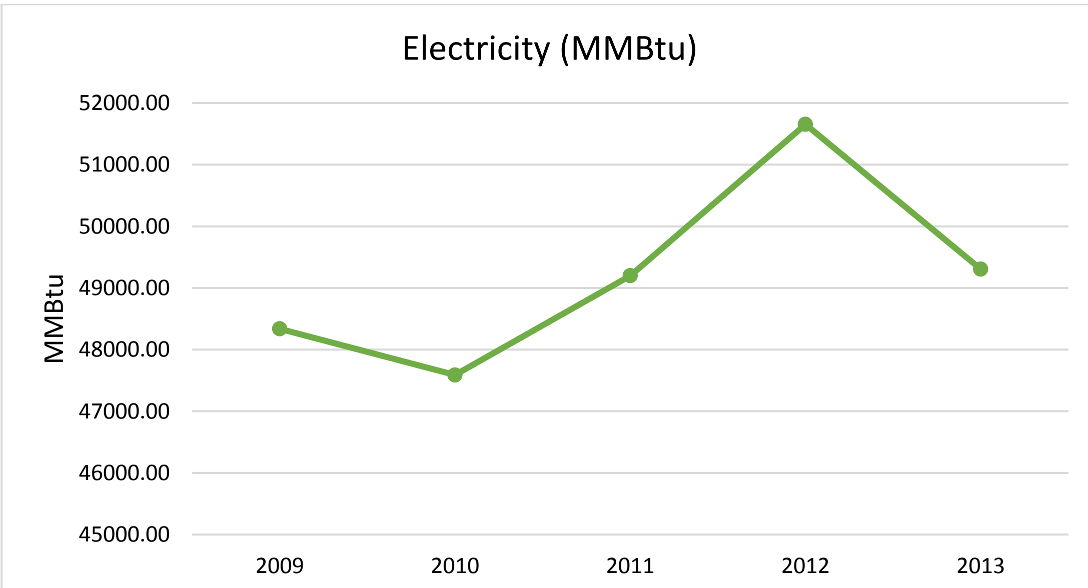
Water treatment facilities, which provide water supply to the city, are large users of electricity and thus are also large GHG emitters. All equipment in water supply systems like pumps and motors operate throughout the day and every single day. Typically, 35% of the energy in municipal energy budgets in the US is allotted to water and wastewater (discussed in the next section) systems (EPA, 2013). In fact, the water supply system of Durham uses the most energy compared to all other local government operations in the City. Increasing the efficiency of these systems can contribute greatly towards reducing the emissions of a city. Efficiency improving measures can be applied at various points in the treatment and distribution process. There are three categories of efficiency improving measures: equipment upgrades, operational modifications, and modifications to facility buildings (EPA, 2013). Besides reducing emissions, higher efficiency also reduces air pollution and cost of electricity through lowered demand and lower cost per kWh. This section attempts to find the effect of efficiency increasing measures adopted at the water treatment facilities.

The Brown treatment plant and the Williams treatment plant are the two water treatment facilities operated by the City of Durham. Their combined capacity is 52 million gallons per day (MGD) and the Brown plant has a capacity about twice that of the Williams plant. MGD is a measure of flow, i.e. volume per unit time. The Williams plant is a base-load plant and it operates continuously on an average of 6 MGD. The water treatment process is similar in both plants and is described here in brief. First, water goes through the raw water pumps, which use about 2 to 4% of the total energy. The water then passes through filters to remove particle media. Backwash pumps of about 150 HP are placed near the filters and they also use 2 to 4% of the total energy used. These pumps pump clean water back through the filter to clean them and prevent buildup of particle media. After filtration, the water is chlorinated and pumped to clear wells where the water is stored. Finished water pumps of about 1500 HP pump the water into the distribution system. There is also a diesel pump for backup in the case of a power failure. Booster pumps are placed at several points along the system. Both plants use electrical energy and there is no significant use of natural gas (Senior Engineer interview, 2013).

The Brown plant has variable frequency drives (VFDs) installed on the finished water pumps and the back wash pumps. They were installed at the end of the calendar year 2010. VFDs are an example of equipment upgrades to increase efficiency. These control the pumps based on variable water requirement as demand varies through the day. VFDs on backwash pumps were installed to regulate the amount of water pumped back through the filters. There was a large amount of clean water pumped back unnecessarily before the VFDs were installed. VFDs are 97% efficient but they also use air conditioners for cooling. The water treatment facilities are run more during off-peak hours than during peak hours in an effort to reduce emissions and costs. Reducing peak demand reduces emissions because during peak hours, dirtier energy is used. This is an operational modification to reduce emissions.

We met in person with an engineer from the Department of Water Management who provided us with details of the treatment process as well as monthly flow, energy and financial data for the facilities from the fiscal year 2011. We also obtained annual energy and financial data for the facilities from the Durham City County Sustainability Office for other years. Data was not available for all years since 2007, the year of the last GHG Inventory report. Monthly data and flow data was available only since the fiscal year 2011.

Figure 13 Combined Electricity Consumption of Water Plants from FY 2009 to 2013



Available data for this analysis were the monthly bills of the treatment facilities and the total treated water in MGD (Senior Engineer 2013). The total treated water data from the Brown plant is not entirely reliable as the meters are outdated and have been subject to much wear. The opinion of the engineer was that the readings most likely had large errors. On the other hand, the Brown plant has extremely accurate magnetic meters and the reported values for this plant are very reliable. Table 11 and 12 show the annual flow, electricity, financial and emission data for the Brown and Williams plants, respectively.

We see that the total electricity used by both plants has no clear trend (Figure 13). Efficiency and emission rate cannot be calculated prior to 2012 but both were almost constant in the last two fiscal years. The effect of the VFDs cannot be quantified with the data provided to us. The devices were installed in late 2010 (calendar year) but flow data is only available from January 2011. From the ICLEI report, we know that efficiency of both the plants combined was 1.2 tons of carbon dioxide per MGD in 2007. The overall emission rate in the year 2012 to 2013 was 1.03 tons of carbon dioxide per MGD, a decrease from the 2007 level.

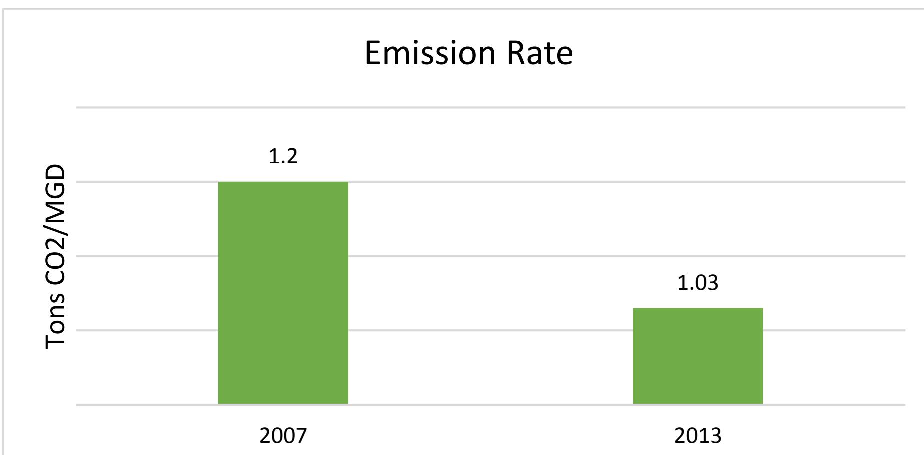
Table 13 Water Flow, Energy Consumption of Brown Water Plant from FY 2009 to 2013

Year	Flow (MGD)	Electricity (MMBtu)	Amount (USD)	CO_2e Emission (tons)	Energy Intensity (MMBtu/MGD)	Emission Intensity (tons CO_2/MGD)
2008-2009	-	34,952.87	567,251.00	7463.85	-	-
2009-2010	-	34,447.55	588,655.81	7355.95	-	-
2010-2011	-	37,007.92	586,728.26	7902.69	-	-
2011-2012	7,280.44	39,726.60	656,887.91	8483.24	5.46	1.17
2012-2013	6,906.39	37,527.49	668,906.96	8013.64	5.43	1.16

Table 14 Water Flow, Energy Consumption of Williams Water Plant FY 2009 to 2013

Year	Flow (MGD)	Electricity (MMBtu)	Amount (USD)	CO_2e Emission (tons)	Energy Intensity (MMBtu/MGD)	Emission Intensity (tons CO_2/MGD)
2008-2009	-	13,384.87	204,659.91	2858.21	-	-
2009-2010	-	13,140.29	211,746.10	2805.98	-	-
2010-2011	-	12,190.39	183,524.91	2603.14	-	-
2011-2012	3,426.00	11,928.35	203,015.47	2547.19	3.48	0.74
2012-2013	3,290.03	11,777.49	216,789.61	2514.97	3.58	0.76

Figure 14 Comparison of Emission Rate between 2007 and 2013



e. Waste Water Project

City Wastewater Facilities

Like the water management plants, wastewater facilities are also large consumers of energy and thereby large emitters. Opportunities exist at various levels in the treatment process to reduce emissions. The City owns and operates two waste water treatment facilities- the North Durham Wastewater Reclamation Facility (NDWRF) and the South Durham Wastewater Reclamation Facility (SDWRF). Wastewater is received at these facilities from city users. There are two stages of clarification with an aeration and anaerobic digestion phase between them. The sludge from anaerobic digestion is then disposed of by land application. After clarification, the water is filtered and disinfected in tertiary treatment using ultraviolet rays. Then the water is finally pumped out and reclaimed (Senior Engineer Interview, 2013).

There were no upgrades to the facilities since the last ICLEI report. However, the flow and electricity data were available to us in Table 13 and 14. Based on this data, we have provided recommendations in Section 7.

Table 13 Water Flow, Energy Consumption of NDWRF from FY 2009 to 2013

FY	Flow (MGD)	Electricity (MMBtu)	Amount (USD)	CO_2e Emission (tons)	Energy Intensity (MMBtu/MGD)	Emission Intensity (tons/MGD)
2008-2009	1620.15	40062.06	1450.84	8390.49	24.72	5.17
2009-2010	1771.67	42486.90	769437.75	8824.87	23.98	4.98
2010-2011	1514.93	43351.98	770564.87	8963.89	28.61	5.91
2011-2012	1519.17	39456.62	806138.55	8106.41	25.97	5.33
2012-2013	1391.03	37570.52	768003.01	7684.77	27.00	5.52

Table 14 Water Flow, Energy Consumption of SDWRF from FY 2009 to 2013

FY	Flow (MGD)	Electricity (MMBtu)	Amount (USD)	CO_2e Emission (tons)	Energy Intensity (MMBtu/MGD)	Emission Intensity (tons/MGD)
2008-2009	1848.2	28743.90	433341.63	6020.04	15.55	3.25
2009-2010	1854.72	30552.46	4,82,981.93	6345.99	16.47	3.42
2010-2011	1669.46	29343.74	4,54,456.72	6067.41	17.57	3.63
2011-2012	1718.44	26533.50	535085.14	5451.34	15.44	3.17
2012-2013	1532.83	22589.17	457246.92	4620.45	14.73	3.01

County Wastewater Facility

The county wastewater treatment facilities have the same treatment process. Most of the plants were built in 2005. There have been operational improvements since 2006. The facility has saved energy by reducing the number of running oxidation dishes. For example, only two rotors are operated out of four rotors at night. Another major upgrade in terms of energy saving aspect was installing a new sludge facility on February 2013. The wastewater was previously transported to a lagoon which creates odor. The new sludge facility saves energy by not re-treating the wastes, and it dries the wastes which reduces smell as well as cost since the wastes are paid by the amount of load. The estimated cost of energy saving was 10%. This facility cost about $10.7 million. Another noticeable aspect for the waste treatment facility is that all buildings are LEED certified, and most energy costs are from water treatment facilities. The department is considering introducing a new solar drying sludge facility in the future. This is a concrete facility, which uses solar energy to dry sludge by installing greenhouse drier in the plant. The amount of dried sludge shipped would be 3 trucks a week instead of 10 trucks a week. This will cost 15 million with 10 year capital plan (Utility Division Manager, 2013). As the department could not provide any data regarding the facilities, we were unable to evaluate emission reductions, if any.

f. Landfill Methane Project

Converting waste into methane production has substantial benefits. On the one hand, it helps utilize the daily waste people produce, reduce GHG emissions, and supply clean electricity for the city; on the other hand, the project reduces financial cost and builds environmentally friendly public image of the city. However, the safety issue of the plant requires particular attention because methane is prone to leaking. In order to achieve this goal, the regular monitoring on site from experienced landfill professionals is indispensable.

The call with the senior engineer from the Department of Water Management was regarding the Landfill Methane Project carried on in Durham. The project is managed by this department, but the trading of electricity generation is operated by a third party entity called Methane Power. The City's primary motivations for the project were (i) offsetting closure cost for the landfill, (ii) long term monitoring and maintenance of the landfill and (iii) sustainability and good stewardship of the city assets.

The formal name of the facility is City of Durham Sanitary Landfill. The Methane Power maintains the blower, hill system, flare, and generators. After accepting the waste from 1984 to 1998, the landfill consisting of 66 wells began producing electricity commercially in 2010 and is estimated to last until 2030. The landfill itself was closed before methane production began. The useful lifetime of methane production on the landfill is estimated to be 30 years depending on the condition of the groundwater monitoring and gas migration. Recoverable quantities of methane will be present for at least a decade beyond that based on the engineer's calculations.

The project was not paid for by the City so the information on the cost of construction is not public record. The electricity is sold to Methane Power on a per kWh basis (1 cent/kWh). As the 66 wells that exist are the responsibility of the City, the engineer from the city government was able to provide us with some data on the project as well as EPA method calculations of GHG emissions. His opinion was that this method is not the most accurate one, scientifically. He also provided us with Landgem calculations related to closure, which is the Landfill Gas Emissions Model provided by EPA and Clean Air Technology Center, but these again are rough estimates.

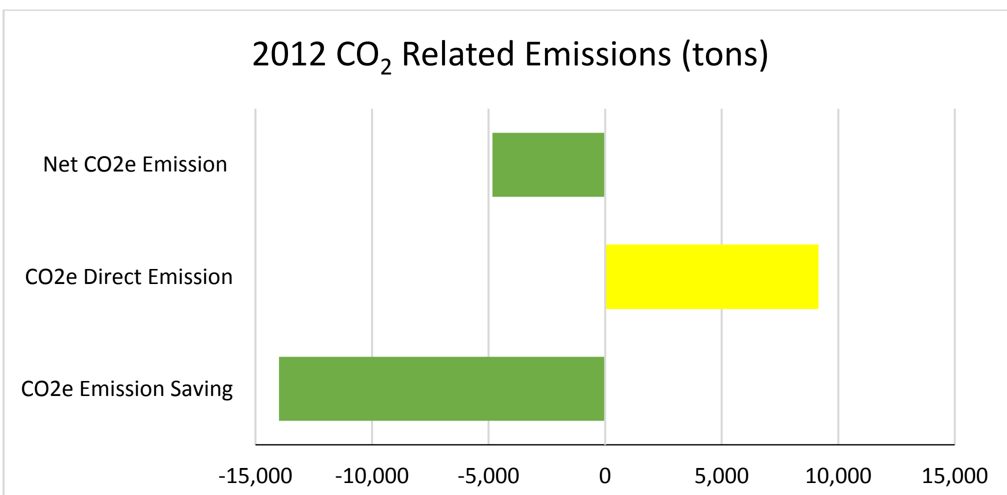
In 2012, the methane gas collection facility possessed a capacity of 1400 acfm (actual cubic feet per minute), and the annual operating hours were around 8766 hours. The measured value of annual collected gas volumetric flow was about 416,175,129 scf (standard cubic feet), indicating the amount of gas production in 2012 contains complex gas content besides methane (Water

Department Internal Report, 2013). According to electricity generation bill provided by the senior engineer, the Durham City was paid $199,548 in FY 2012 and $205,911 in FY 2013 by utilizing methane gas to produce electricity and selling to Methane Power (Senior Engineer, 2014). With the price of $0.01/kWh, the Durham Landfill Methane project generated 19,954,800 kWh of electricity in FY 2012 and 20,591,100 kWh of electricity in FY 2013. By multiplying the emission factor, we calculated the savings of GHG emission which was otherwise emitted by regular sources of electricity generation. However, the landfill plant and power generator also emitted GHG directly, which was about 9,156.8 tons of CO_2 equivalent gases in 2012 according to the data provided by the engineer (Water Department Internal Report, 2013)[4]. Hence in total, the landfill plant saved about 4,831.5 tons of GHG emissions in 2012, which was a huge environmental benefit. However, we didn't have other necessary data for the analysis of 2013. The specific data are shown in the table below.

Table 15 Methane Production and CO2e Emission in FY 2012

Year	Annual Collected Methane Volumetric Flow (scf)	Electricity Generation (kWh)	CO_2e Emission Saving (tons)	CO_2e Direct Emission from the Landfill Plant and Generator (tons)	Net CO_2e Emission (tons)
2012	416,175,129	19,954,800	-13,988.3	9,156.8	-4,831.5
2013	-	20,591,100	-14,434.4	-	-

Figure 15 GHG Emissions of Landfill Methane Project



[4] This emissions data is actually for the normal year 2012, while the savings of GHG emissions with 13,988.3 tons is based on the fiscal year 2012. Therefore, the two numbers actually could not be subtracted directly since they are from different time periods. However, we still deducted 9,156.8 from 13,988.3 because we thought the direct emissions from landfill plant and electricity generator would not change too much for every year. Hence, we assumed the direct emissions for fiscal year 2012 would be the similar number around 9,156.8 tons.

6. Discussion

The scope of our study covers projects implemented and operated by the government sector of a city, which previous studies have not focused upon solely. A large number of existing studies pay attention to national and regional levels or if at the city level, encompass total city emissions including industrial, residential, and community emissions. In addition, the boundary of inventories within such studies varies regarding the inclusion of scope 3 emissions. Cities use different methods of reporting and establishing inventories. In Kennedy et al. (2012), the six cities that were chosen had existing detailed inventories and the authors were able to perform in-depth sector analysis. Each of the cities had at least two recent inventories and emissions could be compared across time. However, our study needed to find the effectiveness of specific projects that the municipal governments have implemented. Durham has also had only one complete greenhouse gas inventory. Therefore our approach was to only collect data that was relevant to each project. The baseline differs across projects as the government departments who provided us with the data had records from varying periods. We were able to compare some figures with ICLEI 2007 report, for example, the overall emissions per metric ton of CO_2 equivalent from the water treatment plants. Others projects like the building upgrades could not be compared to the ICLEI report because data for a number of buildings is missing in both our analysis as well as ICLEI's.

Given the information we acquired, we categorized projects into two main types. The first type of projects is large-scale projects with immediate changes to energy use. These projects include traffic signals, waste treatment, landfill methane, and large buildings projects. If these projects are effective, their results are seen almost immediately. Durham City and County should make sure that proper long term monitoring systems are in place so energy consumption and thereby emissions may be audited and efficiency and emission intensity may also be calculated. New buildings need to be taken accounted for when comparing to the baseline so that increase in emissions due to addition in number of buildings or capacity are not seen as an increase in emissions and show the projects as ineffective. The other type of projects is continuous upgrade projects that occur on a smaller scale with smaller energy improvements. These projects include Fleet and Buildings upgrades and maintenance. These upgrades occur more frequently as vehicles are retired and replaced and buildings are upgraded, however the impacts of these projects are not as apparent right away and long term monitoring and evaluation is required. Moreover, because there are multiple projects, it is hard to keep track of individual project details for review. But it is important to be able to organize and categorize these continuous improvement projects so Durham can analyze the expected long-term reduction of these projects.

Several of the previous studies tend to use per capita emission, which is more suitable for the analysis of national and regional levels that may also include scope 3 emissions. This would be relevant to the community emissions which are not part of our study. For government operations, it is more apt to find total emissions from specific categories of energy usage such as lighting, fleet, water, and building to identify potential opportunities of energy saving. Emission intensity and efficiency are also important factors to consider in our results for each project.

Emission intensity is expressed in metric tons of CO_2 equivalent per mile, metric tons of CO_2 equivalent per unit area, and metric tons of CO_2 equivalent per unit of flow, respectively for vehicles, building and water treatment. These measures are only relevant to each project and cannot be used to compare different projects. We also observe that the average grid electricity coefficients provided by our client (see Table 7) have been decreasing over time as power generation sources become less polluting. Therefore, a part of the GHG reduction is due to electricity sources being less carbon intensive and this is not controlled by Durham City or County. Therefore, emission intensity will decrease over time if all other factors are kept constant. If emission reduction projects are implemented, their effectiveness is overestimated as a result of the emission factor decrease. For an evaluation of just the effects of the government's projects, it is more appropriate to use energy reduction than emission intensity.

Our study will be helpful for those who seek case studies that analyze local government emission reduction efforts. It can be useful for a reference to conduct a similar evaluation in other cities. Cities with similar economic and geographical features of Durham City and County can imitate energy saving initiatives which are applicable for their cities. Given limited data, our report examines how the City and County government can measure and evaluate the progress on the GHG reduction plan within each category: building, lighting, water, wastewater, vehicle fleet, and landfill. Our study can be a guideline of how to keep track of energy saving initiatives in the future. A list of suggested criteria for future inventory is provided in Appendix 3.

Overall, better tracking of project information and expected energy reduction is necessary to sustain long term greenhouse gas reduction, which can reduce the issue of trade-off between accuracy and precision. Despite limited information for building upgrade projects, energy use intensity of County buildings shows a slightly decreasing trend. After few years, it would continuously decrease due to Detention facilities upgrades, which is one of high energy use intensity buildings. The baseline should be adjusted in the future due to new buildings coming online, and a long-time systematically tracking mechanism should be developed.

As discussed earlier from Betsill (2001), cities prefer to have multiple benefits along with emission reduction like social and economic benefits as opposed to solely reducing emissions. However, with limited data we were unable to quantify other benefits. With better records in the future, Durham City and County will be able to perform such an analysis as well.

7. Recommendations

a. Recommendations for each project

The various projects have been effective in reducing emissions in different degrees and this section provides a list of further recommendations. As a major challenge we face was unavailability of data, in the future we recommend to keep clear records of relevant data. The Durham City County Sustainability Office can send annual reminders to each department to record the data to ensure that it is not lost. Here we list a number of further measures to cut the City and County's emissions for these projects as well as four general recommendations which can help in future analysis.

Building Upgrade Project

- **Energy benchmarking of buildings by using energy use intensity.** For example, New York City completed a building benchmarking and created a benchmark score sheet. This enabled the city to identify which buildings to target for the greatest energy savings in comparison of the national average. To do energy benchmarking of buildings, developing a consistent way of measurement to track performance is critical to compare it with other buildings. In addition, benchmarking can benefit improving operation and maintenance practices in efficiency by building information.

Transportation Project

- **Upgrade fleet vehicle into hybrid alternatives.** There is a huge opportunity to upgrade existing passenger vehicles in fleet. Currently passenger vehicles have lower miles per gallon (MPG) than SUVs, while hybrid vehicles have significantly higher MPG than the average. If hybrid vehicles are not an option, then purchasing efficient gasoline passenger vehicles can also improve the overall fleet efficiency. The police department can also test hybrid vehicles to see if vehicle efficiency in the department can be improved.
- **Expand hybrid DATA bus in public transportation.** Hybrid buses possess a significant efficiency improvement over non-hybrid diesel buses. There is greater efficiency advantage when hybrid buses are used in stop and go traffic, so hybrid buses can be placed in frequently traveled local routes. It's also important to monitor available federal and state rebates for public transportation vehicles for future hybrid bus expansion.
- **Continue monitoring of electric vehicles**. With only a few full electric cars in fleet, there is not enough data to determine if they can fully replace certain passenger vehicles and reduce significant amounts of greenhouse gases. However, with tax credits and other incentives, electric cars can be an attractive alternative for wider adoption in local government.

Traffic Signal Project

- **Continue upgrading traffic signals with LED lights, and manage to have all traffic signals with LEDs in Durham by 2015.** Currently, there are 95% of the 403 traffic signals using LEDs, the government should also continue upgrade the remaining 5% of signals with

LEDs. Meanwhile, as the total number of traffic signals is increasing every year, the new traffic signals should be installed with LED lights directly.

- **Expanding streetlight project to whole Durham area.** As mentioned before, there is only a small project of upgrading streetlights with LEDs in Durham. In order to achieve better environmental benefits as is shown from the traffic signal project, we recommend expanding the streetlight project to whole Durham area, that is, to install more LEDs in streetlights.
- **Pilot program of applying clean energy to streetlights in Durham**. For example, each streetlight can be installed with a small solar power system, so that the solar panels can absorb energy in the daytime, and convert it to electricity at night self-sustaining the energy demand of streetlights. They can even be combined with wind power, which can save up to 100% of out-sourced energy (DMX LED Lights, 2014). However, this idea may not be feasible to traffic signals as they require stable function as well as stable energy supply for guiding the traffic.

Water Management Project

- **Maintain monthly records of flow data, energy usage and billing information.** These data are readily available for the department and they should be recorded. The main obstacle for our analysis was the lack of data and maintaining records should make future assessments easier.
- **Replacement of Brown plant meters in phases.** The readings from the existing meters are not very accurate and replacing them will give more reliable data.

Wastewater Management Project

- **Install variable frequency drivers in treatment facilities.** Variable frequency drivers were effective in the water management systems. They will help increase energy efficiency
- **Install energy efficient pumps and blowers.** The most energy intensive parts of the treatment process are pumping and aeration. Using more efficient devices will help reduce emissions.

Landfill Methane Project

- **Monitor the plant and record the data continually.** The data available to us are only for 2012. It would be more beneficial to have tracked the data of the plant since 2010 when methane began to produce electricity. Therefore, we strongly suggest the City government to continually monitor and measure the plant in future to compare the annual change of gas and future GHG saving potential.
- **Continue the project and exploit a new landfill plant.** As the current landfill plant indeed provides environment benefits, we recommend the government to continue the methane project. And if possible, the city can exploit a new landfill plant in Durham to utilize the daily waste effectively from now on, in order to generate clean electricity and save more GHG emissions in future.

b. Recommendations for Durham City and County

The overall recommendations for Durham City and County governments are summarized into four categories, which can also be useful to other cities that will conduct similar Greenhouse Gas Reduction Initiatives.

- First, we recommend that Durham City and the County should re-evaluate greenhouse gas reduction targets for the existing projects or new projects in each section: transportation, waste water, lighting, and buildings. The current goal of Durham City and County government is 50 percent reduction of greenhouse gas emissions from 2005 levels by 2030. Each local government entity does not state specific goal and objectives of each project implemented, and the goals have not been renewed since 2010. The clear goal and objective setting would enable to create quantifiable criteria and a measurable evaluation method. In order to set the clear goal and objectives, the City and County need to know their operational, technical, political, and financial limitation to maintain current projects or to develop new initiatives. The first step to take would be researching total energy reduction potential in each category.

- Moreover, we noticed that providing training to facility management team on available technologies and best practices is critical to assist them in maintaining system in an energy efficient manner. Since we could not collect enough data to analyze and evaluate previous projects and to examine further opportunities, explaining to them about why their job is important in tracking energy data and achieving the City and County's goal could help them be aware of projects and energy saving.

- From the technical aspect, the local governments should consider installing advanced metering for major energy-consuming facilities to improve energy efficiency and to track data. For example, metering for Brown water treatment plant is currently not reliable to analyze. To improve such technical barriers, the governments should identify possible funding sources required to build on existing projects and to implement new initiatives.

- Last, more collaborations are suggested not only between each government department, but also between the government and private sector. Forming a steering committee for better communication between each department is highly recommended. Engaging the private sector is beneficial to assist result-oriented projects, for example, through performance contract, which can introduce local/regional funding and advanced technologies to the government.

Based on our experience of researching Durham City and County case, setting quantifiable criteria to measure performance of projects is critical. Keeping track of reliable data is also significant to evaluate the performance. Developing a score card to measure performance will be helpful for the purpose of comparing performance each year. Based on the score card, offering incentives to the department that achieved most energy saving is one way to increase awareness and to encourage employees and facility management team.

8. Limitations

There were similar challenges we encountered while evaluating all the above projects. A common problem for most of the projects we discussed was the lack of data. Officials at the various departments did not always provide us with complete data. In several cases, there were no records of the data even with the respective departments. In a few instances, some of the available data was not always reliable.

Our report cannot be compared to the previous report by ICLEI for all the projects because of inconsistencies in data collection. Our study scope is very different from ICLEI's scope that includes community inventory and public school operations. Another reason is that most project upgrades were installed a few years after the ICLEI report was published. Thus, when the goal is to find the effectiveness of the upgrades, a comparison of emissions prior to and after the implementation of upgrades and finding an overall trend in the emission data is more meaningful than to compare with the baseline established by ICLEI.

The data available to us were not in the same time period. Therefore, we cannot compare which project is more effective and helpful for reducing GHG emissions under the same year. We also did not account for weather effects which can influence energy consumption in our analysis, still due to the incompleteness of data. Specific challenges and limitations of projects are listed below:

Buildings Upgrade Project

- The square footage data for the buildings was not available as a result of which it was not possible to calculate building energy efficiency. ICLEI faced the same problem that they were able to obtain the square footage data for less than 25% of buildings (ICLEI, 2007c).
- The exact dates of the building upgrades were unavailable so a comparison of energy use before and after the upgrades was not possible.

Transportation Projects

- City fleet department was not able to provide any vehicle miles or fuel consumption data
- Duration of available data was inconsistent and therefore not suitable for comparison

Water Management Project

- Flow data for water management facilities was available only from 2011, although wastewater records were available from 2000.

- Monthly energy data was not available for both water and wastewater prior to 2011. Therefore, the energy usage could not be compared over seasons.
- The flow data for the Brown plant are not entirely reliable because the meters are outdated and worn. On the other hand, the Williams plant readings are extremely accurate because of magnetic meters that were installed.
- The effect of operational measures to reduce efficiency like operating the water treatment plants more during off-peak hours is beyond the scope of this analysis.

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Appendix 1

A list of Durham City buildings by sector:

Fire Stations	Fire Station No. 1 Fire Station No. 2 Fire Station No. 3 Fire Station No. 4 Fire Station No. 5 Fire Station No. 6 Fire Station No. 7 Fire Station No. 8 Fire Station No. 9 Fire Station No. 10 Fire Station No. 11 Fire Station No. 12 Fire Station No. 13
Community and Recreation Center	E Durham Comm Ctr E D Johnson Com Ctr Weaver St Rec Ctr E D Mickle Rec Center Morreene Rd Rec Ctr W D Hill Rec Center PR I R Holmes Rec Ctr Walltown Rec Ctr W.I. Patterson Rec Ctr
Police	Central Dist. Police Substa. Police Headquarters/ Communications Center
Maintenance	Fleet Maintenance Bldg Coach Maintenance
Waste Facility	Durham Transfer Station Solid Waste Mgt 1 Solid Waste Mgt 2
Other Facility	Old CSI Traffic Signal/Sign Shop Radio Tower Sign Shop
Offices	City Hall/ Annex OC-GS DBAP City/County Planning Dept Data Administration Laidlaw Administration Armory

	Prop Facil. Mgt
	Employee Training & Development /Parks Rec
Park	Southern Boundary Park
	Elmira Park
	Southern Boundary Park PR
	Hillside Park
	Twin Lakes Park
	C. M. Herdon Park
	PR - Mangum Hse/Eno Pk
	PR Barn
	PR Westpoint Eno
	Pineywood Park
	Long Meadow Park: Bath House, Pool Pump House
	PR Westpoint Blacksmith
	T A Grady Center PR
	Forest Hills Clubhouse & Offices
	Southern Boundary Park PR

Appendix 2

A list of Durham County buildings by sector:

Administrative Offices	Administrative Complex Agriculture Building Carmichael Building DSS Engineering Law Building General Services Cplx Social Service Building (Main) Fire Marshal's Office Health Department
Emergency Medical Services	EMS #2 EMS Holloway (Station 4) EMS Lebanon (Station 6) EMS Stadium Dr. (Base) Emergency Medical Services Total
Recreation	Memorial Stadium (County Stadium)
Community centers and offices	Community Shelter Youth Home Operation Breakthrough
Libraries	Bragtown Branch Library East Regional Library Main Library N Durham Branch Library Parkwood Branch Library Southwest Branch Library Stanford L. Warren Library
Detention Facilities	Detention Facility Jail Annex Criminal Justice Rec Ctr
Judicial buildings	Judicial Building (+prkn) Judicial Building Annex OSL Judicial buildings Total
Other facilities	Animal Control Animal Shelter Durham Center Access
Police	Sheriff Eastern Satellite Station Sheriff's Firing Range

Appendix 3

A list of criteria to consider when accounting inventories:

- Buildings: the date of beginning and ending projects, number of employees, square footage of buildings, number of new buildings, what building to include, operational information, machine information, energy efficiency of machines.
- Lighting (Traffic Signal): number of traffic signals, installation rate/increasing rate per year, the performance of the light bulbs, total energy consumption, electricity generation sources.
- Water: monthly water flow in MGD, monthly electricity consumption in kWh, monthly cost of electricity
- Fleet: vehicle miles travelled, fuel consumption
- Landfill Methane: landfill capacity and lifetime, operating hours, annual collected gas flow volume, electricity generation, landfill and generator direct GHG emissions.