

A Greenhouse Gas Emissions Inventory for the Borough of State College

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January 2008
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Foreword

This report represents a collaborative effort between a course at Penn State and the government and community of the Borough of State College, Pennsylvania. *Geography 493, Service Learning: The Centre County Community Energy Project* is an ongoing course devoted to encouraging residents of Centre County, Pennsylvania to use their energy resources more wisely.

For the last three semesters, Geography 493 has focused its efforts on helping the Borough of State College develop a greenhouse gas mitigation plan. In fall 2006, students compiled a greenhouse gas emissions inventory for the Borough, thereby determining the human activities responsible for those emissions and setting a baseline with which to compare future emissions. Spring 2007 saw another group of students conduct focus groups with Borough stakeholders to identify several dozen potential greenhouse gas reduction options. In fall 2007, yet another group of students took the options identified the previous spring and fleshed them out.

Spring 2008 will see the conclusion of the student work with the Borough. At that time, students will conduct more focus groups at which Borough stakeholders will evaluate the options presented in this report and develop a formal greenhouse gas mitigation plan.

The goal of this four-semester sequence is not for Geography 493 to dictate and manage the Borough's mitigation plan, but instead for the students to encourage and facilitate Borough construction and adoption of such a plan. The course was at least partly successful because the State College Borough Council passed a formal declaration as a climate protection community in August 2007. We hope that this report will complement the declaration and will further the work of the Borough government and residents towards a more sustainable future.

This report is a complete rewrite of the fall 2006 greenhouse gas emissions inventory. It updates calculations and corrects errors. We thank Dan Morath, a Senior in Geography, for taking on this yeoman's task. We give special thanks to the original student team—Lisa Boren, Ron Feingold, Eric Lumsden, Ian Smith, and Andy Terbovich—plus Ed Wells, Chair of the Environmental Studies Department and Associate Professor of Environmental Studies at Wilson College, who compiled the fall 2006 inventory.

Brent Yarnal and Howard Greenburg
January 2008

Introduction

Everyday human activities can lead to climate change. Agriculture, forestry, fossil fuel production and combustion, chemical manufacture and use, waste disposal, and other activities release greenhouse gases.¹ According to a worldwide consensus of climate scientists, these greenhouse gases accumulate in the atmosphere, increase the trapping of heat in the lower atmosphere, and in the process eventually change Earth's surface climate. It is important to note that atmospheric greenhouse gases and their trapping of heat near the surface are normal and necessary to life, but that human activities are raising greenhouse gas concentrations and surface warming above natural levels. The resulting climate change has already been found to have adverse effects on plants, animals, human health, and various natural systems. Climate change may have potentially catastrophic effects if greenhouse gas emissions are not curtailed significantly in the coming decades (Houghton et al., 2001).

Until the 1990s, most efforts to identify the human activities producing greenhouse gases and to measure their emissions focused on the global level. At the global scale, the greenhouse gases considered here diffuse and mix regardless of their points of origin. This universal mixing makes it difficult to use instruments for measuring greenhouse gas emissions at sub-global scales. Instead, analysts must infer the emissions from human activity. Most countries keep broad records of land in forestry and agriculture, production and consumption of fossil fuels, chemical manufacture and use, waste disposal, and other major human activities within their boundaries. It is relatively straightforward, therefore, to construct national inventories of greenhouse gas emissions from general human activity data. The United States has used this approach to compile greenhouse gas emissions inventories since the late 1980s (McCarthy et al., 2001; EIA, 2001).

In a large, diverse country like the United States, however, the mix of human activities and resulting greenhouse gas emissions varies from region to region. For instance, states dominated by agriculture, heavy manufacturing, or coal mining, such as Kansas, Ohio, and West Virginia, respectively, emit markedly different bundles of greenhouse gases. If the United States were to develop a national action plan to reduce emissions, but failed to account for state-by-state differences, it is unlikely that the action plan would succeed because it would lack the detail to be cost-effective and fair across and within regions (EPA, 2001; AAG, 2003). To develop an effective plan for greenhouse gas mitigation, states and localities must first compile emissions inventories (Rose and Zhang, 2004).

Recognizing the need for state-level action to decrease greenhouse gas emissions, the United States Environmental Protection Agency (EPA) has encouraged states to compile emissions inventories for nearly two decades. The state-level emissions inventory protocols (Rose, 2003) use the international reporting standard established by the Intergovernmental Panel on Climate Change (IPCC, 1997) and expanded by EPA (EIA, 2001). The greenhouse gases cataloged by United States emissions inventories include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and certain manufactured fluorinated gases commonly known as ozone depleting compounds (ODCs), substitutes for ODCs, and some other man-

¹ This introduction is modified from the introduction of Rose et al. (2005)

made compounds. ODCs were banned under the Montreal Protocol and are no longer included in greenhouse gas emissions inventories. The sectors tracked by greenhouse gas inventories include the activities associated with agricultural production, forestry, energy production and consumption (including transportation), other industrial processes, and waste disposal.

Not only is there great diversity from state to state, but also there is tremendous variation within most states. In Pennsylvania, various cities, counties, and regions are known for their agriculture, forestry, coal mining, transportation systems, manufacturing, or refuse disposal. Ultimately, substate-level entities—metropolitan regions, counties, small cities, and even universities—will need to compile inventories and formulate action plans (AAG, 2003). Several recent efforts have recognized that need. Included among those efforts is the US Mayors Climate Protection Agreement, signed by more than 750 mayors by January 2008, which aims at significantly reducing greenhouse gases from their cities through actions ranging from anti-sprawl land-use policies, to urban forest restoration projects, to public information campaigns. Many of the signatory cities have inventoried their greenhouse gas emissions, with more inventories on the way.

In summer 2006, a group of environmentally concerned members of Saint Andrew's Episcopal Church in State College, Pennsylvania approached Penn State's Center for Integrated Regional Assessment (CIRA) about the possibility of conducting a greenhouse gas emissions inventory for the Borough of State College. CIRA Associates and students had conducted inventories for the state of Pennsylvania (Rose et al., 2005) and had worked with the Penn State administration to inventory the University's emissions (Steuer, 2004; Knuth et al., 2007) and to help the University develop a mitigation plan (Knuth et al., 2007). CIRA's Brent Yarnal, Director, and Howard Greenberg, Senior Research Associate, volunteered to develop a service learning course in which undergraduate students would work with stakeholders from the Borough to inventory emissions and develop an action plan. The State College Borough Council approved this plan in fall 2006.

This report is the result of student efforts. In fall 2006, five Penn State students and a visiting faculty member from Wilson College worked with State College Borough and other residents to gather data and compile the original greenhouse gas emissions inventory. In fall 2007, that inventory was completely revamped and the report rewritten to form this document.

The following section reviews the greenhouse gases considered here. Next comes a brief overview of the six sectors considered in the inventory—electricity, transportation, on-site fuel combustion, solid waste and liquid wastes, and synthetic chemicals—followed by a detailed account of each sector. The detailed sector accounts provide information on the methods used and greenhouse gases emitted by the sector, and also include a discussion of important points emerging from the sector inventory. Each sector's results will be compared to similar results from the greenhouse gas emissions inventory for Tompkins County, New York (Fay, 1998). Tompkins County, or more specifically the city of Ithaca and home of Cornell University, offers a unique parity to State College. Finally, the report presents

overall results of the inventory and some concluding thoughts. Appendices provide the calculations used for each sector.

Special note on the scope of this report

Ideally, a greenhouse gas emissions inventory should cover a range of years, track long-term trends in emissions, and show the results of mitigation efforts. The best inventories use raw data, start in 1990 or earlier, and continue to the near present. Unfortunately, it is rare for such data to exist for a municipality like the Borough of State College.

At the time of the original compilation of this inventory in fall 2006, the only period for which data were available in all the relevant sectors was calendar year 2004. Consequently, this inventory is limited to 2004. For the purposes of this report, it is assumed that 2004 was a typical year in terms of its greenhouse gas emissions.

This inventory not only is limited in time, but also in space. It covers the Borough of State College, but does not include either the Penn State University Park campus or the townships surrounding the Borough.

It must be stressed that for a mitigation plan to succeed, inventories should be compiled at regular intervals, with annual inventories being ideal. To compile annual inventories, data collecting and archiving must be an ongoing process—or else vital data will be lost and inventories will be incomplete.

Greenhouse Gases

While there are many different compounds that can have an effect on global warming and the greenhouse effect, EPA recommends the inventorying of four major gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases.

Carbon Dioxide

Since the late 1800s, concentrations of CO₂ have risen about 30% above pre-industrial levels. Those concentrations are now higher than they have been for over 400,000 years. Although CO₂ is a natural component of the atmosphere, human inputs of this gas through burning coal, petroleum products, and natural gas greatly exceeds natural concentrations. Further, forest clearing has released additional large quantities because trees are a natural sink for CO₂. Although each molecule of this gas produces a relatively weak greenhouse response in the atmosphere, the vast volume of CO₂ released each year by human activity—over six billion tons—causes it to be the gas that contributes most to global warming and the focus of the greatest attention (Forster et al., 2007).

Methane

CH₄ acts as a greenhouse gas more than 20 times more powerful than CO₂. This means that over a 100-year period, one pound of CH₄ is 21 times more effective at trapping heat than CO₂. However, CH₄ has a much shorter atmospheric lifetime than CO₂, lasting only between 9-15 years in the atmosphere. Because of its strong heat trapping capabilities and short lifetime, significant reductions in the emissions of CH₄, can have measurable results in the atmosphere within a decade. There are many sources of methane, but the most important sources associated with human activity are fossil fuel extraction, rice paddy cultivation, fermentation in the guts of ruminant animals, animal wastes, domestic sewage, landfills, and biomass burning (Forster et al., 2007),

Nitrous Oxide

Nitrous oxide (N₂O) represents around a small fraction of total greenhouse gas emissions in the United States (EIA, 2004), but is about 300 times more powerful as a greenhouse gas than carbon dioxide and stays in the atmosphere over a century, so it still contributes to 5 percent of the national contribution to global warming. The largest source of nitrous oxide emissions is from agricultural soil management (EPA, 2006), mainly from nitrogen fertilizers. Nitrous oxide is also emitted in organic decomposition of sewage and manure, as well as from the combustion of fossil fuels.

Fluorinated Gases

Unlike CO₂, CH₄, and N₂O, this category of greenhouse gases do not occur naturally; they are man-made. There are dozens of types of fluorinated and related greenhouse gases. Worldwide, the man-made gases make up roughly one quarter of the human contribution to

global warming. In theory, mitigating these gases should be relatively easy because they are under human control. However, because they are used for some of the most important aspects of modern life, such as air conditioning, refrigeration, computer manufacture, and fire suppression, it is difficult for people to stop using them.

Chlorofluorocarbons (CFCs) are powerful greenhouse gases. CFCs were used for many purposes, including refrigeration, air conditioning, packaging, insulation, solvents, and aerosol propellants (IPCC, 2001). After it became apparent that CFCs destroy the ozone layer, they were banned under the Montreal Protocol in 1987. Although their eventual elimination will help the problem of global warming, some of the other fluorinated gases used to replace CFCs are also greenhouse gases, but are not covered under the Montreal Protocol. Two types of these gases, the hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs), are both long-lived. HFCs are often used as refrigerants and in the creation of semiconductors. Each pound of HFCs is estimated to be 1,300-11,700 times more powerful greenhouse warmers than a pound of CO₂. PFC molecules are also used in the semiconductor industry, but are also emitted as by-products of uranium enrichment and aluminum smelting. Their warming potential ranges from 6,500-9,200 times greater than the potential of CO₂.

Overview of Sectors

Electricity

Greenhouse gases are emitted during the production of electricity from power plants or on-site generators. We only inventoried consumption from power plant-fed electricity because we lacked a feasible way to inventory on-site generated electricity, which only accounts for a very small portion of electricity consumption. Note that in the accounting system used in this report, although the electricity is generated—and the resulting GHGs are produced—outside the Borough, residents, businesses, and others consuming that electricity in the Borough makes them responsible for the emissions.

Transportation

Nationally, transportation is responsible for a third of greenhouse gas emissions, but can be accountable for higher percentages locally. Emissions from this sector are difficult to inventory, but important to any mitigation plan because transportation is relatively easy to influence through technological innovation and management.

On-Site Fuel

Emissions from this sector result from businesses or individuals who heat space and water with fuels such as utility natural gas, kerosene, or wood. Such emissions are not important nationally, but can be important locally.

Waste

The waste sector consists of solid waste in landfills and liquid waste from sewage. Anaerobic decomposition of these wastes emits methane and carbon dioxide. Methane from these sources can be large locally and are an important component of a municipal greenhouse gas emissions inventory. Carbon dioxide emissions are not recorded in greenhouse gas inventories since these emissions are counted as part of the natural carbon cycle and therefore considered carbon neutral (EIIP, 1999).

Synthetic Chemicals

Synthetic chemicals can be significant components of local greenhouse gas emissions. However, the absence of heavy industry and agriculture, two of the biggest contributors to this sector, within the Borough makes it likely that synthetic chemical emissions will be extremely low when compared to emissions from other sectors.

Electricity Sector

Overview

The Borough of State College, like many places in America, utilizes a large amount of electricity generated by processes that emit greenhouse gases. Greenhouse gas emission inventories often show that the electrical power sector is the largest source of CO₂. Thus, electricity production and consumption is a vital sector for study in any greenhouse gas emissions inventory.

In Pennsylvania, burning coal is the most common way to generate electric power. Coal, while relatively economical, releases an average of 2,249 lbs CO₂/MWh when produced in America (EPA, 2006a). This section of the report will address the emission of CO₂ from fuel combustion for the generation of electricity. Carbon dioxide emissions will be converted into metric tons of carbon dioxide equivalent (MTCO₂E) in this and all other sectors in this report.

The State College area is served entirely by Allegheny Power, which operates by distributing electricity from the Pennsylvania-New Jersey-Maryland (PJM) Interconnect power pool. Although the emissions from these plants are not generated inside of the Borough, those emissions are attributed to the location of consumption.

The fuel mix that goes into the electrical grid dictates the amount of CO₂ emissions. PJM Interconnect runs many different power plants that feed into the grid (PUC, 2004). Consequently, it is impossible to say what type of plant produced the electricity used in State College (Kearney, 2006). Nonetheless, PJM reports the average annual composition of their fuel mix across the grid. Furthermore, the company reports to EPA the average amount of CO₂ emitted per kilowatt-hour supplied (EPA, 2006a).

Methodology

Allegheny Power supplied the electricity data for the area based on monthly kilowatt-hour use. These data were segregated by zip code and rate code. The rate codes correspond to five sectors: (1) residential, (2) small commercial, (3) large commercial and small industrial, (4) large industrial and (5) street and area lighting. Since the Borough of State College does not have significant large commercial or industrial areas, this sector is omitted from this study.

When this inventory was compiled, Allegheny Power could only supply 18 months of data, from March 2004 to August 2005 (Kearney, 2006). These data were normalized to one year by averaging together any months that were reported twice (i.e., March-August), thereby providing 12 months of data for March 2004 to February 2005. We assumed that January-February 2005 were identical to January-February 2004.

Data were reported per zip code, but the Borough of State College does not conform to zip code boundaries. Thus, we used per capita scaling to fit the data from zip code to the Borough, focusing on zip codes 16801 and 16803, which encompass the area of the Borough north and south of the Penn State University campus as well as much of the surrounding locale.

To establish the population of State College Borough residents living within these zip codes, we contacted Carl Hess, State College Planning Director. Hess (2007) explained that these populations could be determined by looking at census tract population. He gave us the census tract numbers for State College Borough, and explained which ones fall into each zip code. With that information, we were able to verify the populations using the U.S. Census Website. After calculating per capita consumption for each of the two zip codes, Borough consumption was deciphered by multiplying each value by the estimated Borough population residing within each zip code. For a more detailed explanation of how the population and consumption data were determined, refer to Appendix A.

We obtained statistical data directly from PJM (2004) to calculate CO₂ emissions per kilowatt-hour of consumed energy in the Borough. Because of State College’s geographic location, we assumed that all electricity supplied by Allegheny Power to the Borough is a result of coal-fired energy.

With kilowatt-hour usage of State College Borough for 2004 and pounds of CO₂ per kilowatt-hour produced for the same year, we multiplied these data together to yield emissions in terms of pounds of CO₂ produced by State College Borough. We converted pounds of CO₂ to MTCO₂E. A systematic explanation, including equations detailing this process, is presented in Appendix B to clarify these procedures.

Results

The residential sector is the largest emitter of GHGs in the Borough, followed closely by the small commercial sector. While street and area lighting does contribute to emissions totals, it has a minimal impact. Total consumption from all sectors was 186,999,308 kWh. The annual emissions in MTCO₂E are presented in Table 1.

Table 1: CO₂ Emissions due to Electricity (MTCO₂E)				
	Residential	Commercial	Lighting	Total
2004	60,025	40,887	387	101,229

Discussion

The short range of data available for this sector is disabling. For long-term energy studies, 18 months is insufficient to produce a viable trend. As a result, this lack of data was

the most limiting factor of this report. Since we were unable to procure multiyear datasets, we are unable to report on the variability surrounding GHG emissions in State College Borough.

Another problem is the scale difference between Borough and zip code boundaries. To determine accurately the Borough's electricity consumption from the data, these data had to be scaled down. While per capita scaling methods are commonly used in inventories where data are not available at the municipal level, there are several inherent problems in doing so. For example, per capita scaling in the commercial sector does not reflect the variation in business type and density. Ideally, the electrical data would be recorded with a variety of boundaries, such as zip code, borough, county, etc., to facilitate studies on various scales and circumvent the need to devise specific scaling factors.

Within this sector, most of the weaknesses can be attributed either directly or indirectly to the problems of data span and boundary scaling. However, there are several other areas of concern. One source of error concerns PJM Interconnection. Because of the size of PJM, the emissions data include power plants throughout more than a dozen states. This creates a more balanced blend of fuels than exists in Pennsylvania, a high coal state. According to Allegheny Energy (2006), their generation facilities are composed of about 95% coal power plants. If it were possible to determine where the electricity in State College came from, it would most likely result in more coal power being used and therefore significantly more CO₂ emitted. However, Kearney (2006) informed us that by the nature of the power grid, this would be impossible to determine.

For all of the problems listed above, it is still possible to draw conclusions from the results. The sector emits roughly 31% of the Borough's total emissions. This number can tell us two things. First, it may indicate possible inaccuracies in the data from this and other sectors. Most inventories attribute over 50% of the total GHG emissions to the electrical sector (EIIP, 1999). Refining this report by collecting better data over time could make it more accurate. Second, even at 31% of the total emissions, the electrical sector is still one of the largest sources of emissions in State College Borough and deserves emphasis in any mitigation plan.

In future iterations of the inventory, steps should be taken to refine this sector's data. One recommended step is to begin tracking Borough electricity consumption on a monthly basis and building a long-term picture of State College's consumption.

Comparison

Compared to Tompkins County, NY, State College Borough has far less emissions from total electricity and per capita consumption (Table 2). While per capita emissions in the residential sector demonstrate parity, we see that the same is not true for the commercial/industrial sector. The explanation for this difference may be that most commercial/industrial activities emitting significant amounts of GHGs in Centre County lie outside the Borough; the Tompkins County inventory includes these activities. It is also

Table 2: State College and Tompkins County Emissions from Electricity (MTCO₂E)				
	State College	State College Per Capita	Tompkins County	Tompkins Per Capita
Residential	60,025	2.23	251,358	2.60
Commercial/Industrial	41,274	1.53	341,143	3.54
Total	101,229	3.75	592,501	6.14

important to note that Tompkins County has a much higher population than the Borough, at 3.5 times that of State College.

Transportation Sector

Overview

State College Borough, like many college towns, is a transportation hub. Cars, motorcycles, trucks, and buses crowd the downtown streets each day, contributing significantly to the Borough's GHG emissions. Drivers include not only State College residents, but also the transient commuters and freight haulers who only travel through the Borough temporarily, but still contribute emissions. Nationally, the transportation sector accounts for one third of GHG emissions. In 2004, the US contributed 314 million metric tons of CO₂ from personal vehicles alone (DeCicco and Fung, 2004). Thus, transportation is another vital sector for study in this greenhouse gas emissions inventory.

The major greenhouse gas associated with vehicle emissions is CO₂, resulting from the combustion of fossil fuels (DeCicco and Fung, 2004). Gasoline is the primary fuel used in light duty personal vehicles, such as cars, motorcycles, SUVs, and pickup trucks. The average per capita consumption of gasoline in the US in 2004 was 465 gallons. The EPA estimates that each gallon of gasoline burned by a vehicle's internal combustion engine yields approximately 19 lbs of CO₂. For diesel fuel, the estimate is slightly higher, at approximately 22 lbs of CO₂. Diesel is used less extensively for personal vehicles, fueling most heavy-duty trucks and off-road equipment. Many city bus fleets are fueled by diesel as well. However, State College Borough's bus fleet, the Centre Area Transportation Authority (CATA), switched from diesel fuel to natural gas in 1997 (Steuer, 2004).

Methodology

To estimate CO₂ emissions in the transportation sector, we needed to establish the total number of vehicles per vehicle type driven in State College Borough for the year 2004. We obtained vehicle registration data per vehicle type from the Federal Highway Administration (FHWA, 2006). The data were available at both the national and state level. To increase accuracy, we started at the state level and scaled our data down. We used per capita scaling to assume the number of vehicles registered to State College Borough. After calculating per capita vehicle registration for the entire state, that value was multiplied by State College Borough's population to find the number of cars in the Borough. For population information, refer to Appendix A.

Next, we needed to determine the amount of fuel consumed per vehicle in State College Borough. Consumption data were available at the national level from FHWA (2006). Again, we performed per capita scaling to estimate gallons of fuel consumed per vehicle in State College Borough by first synchronizing registration and fuel consumption data according to vehicle type, collapsing type into three main categories. The first category, 'automobiles,' combined motorcycles, cars, SUVs, and light pick-up trucks. We assumed that vehicles falling into this category operated using gasoline. The next category, 'trucks,' combined heavy duty single-unit 2-axle 6-tire or more trucks with combination trucks. In

this category, we assumed that diesel was the operating fuel. The final category included only buses.² We used national vehicle registration data found at the Federal Highway Administration’s Website to calculate fuel consumed per vehicle.

Recalling the number of vehicles in the Borough from our previous calculation, we multiplied the number of vehicles by fuel consumed per vehicle to get the total gallons of fuel consumed in State College Borough. Next, we used the EPA (2007) method for estimating CO₂ emissions per gallon of fuel consumed (19 lbs/gallon for gasoline and 22 lbs/gallon for diesel). We converted pounds of CO₂ to MTCO₂E. A systematic explanation, including equations detailing this process, is presented in Appendix C to expand and clarify these procedures.

Results

Automobiles contribute the most to State College Borough’s GHG emissions from transportation. Total consumption was 12,382,657 gallons of gasoline and 151,359 gallons of diesel. Table 3 summarizes annual emissions calculated for the transportation sector.

Table 3: CO₂ Emissions from Transportation (MTCO₂E)				
	Automobiles	Trucks	Buses*	Total*
2004	117,743	171	1,344	119,257

Discussion

Data for this section were, by far, the most difficult to find. Therefore, data were not to scale and were grossly estimated to downscale to the municipal level. Although we made these estimates using accepted methods, these methods require many assumptions and do not acknowledge many factors that control GHG emissions.

One issue involved estimating the number of trucks in the Borough. Based on a value of 0.31 trucks per capita in the state of Pennsylvania, the calculation yields approximately 8,240 trucks—a gross overestimate. To remedy this problem, we chose to include only those trucks registered as part of the State College Borough Fleet. Eric Brooks, State College Borough Operations Manager, supplied a list of Borough vehicles. Of the 109 vehicles listed, 50 were considered heavy diesel-powered trucks or off-road equipment. This number is probably an underestimate, but is much more accurate than 8,240. The source of this problem is the lack of documentation of registered vehicles at the municipal level.

Still, even if Borough vehicle registration were ideally documented, we still assume that only those vehicles contribute to Borough emissions. This method disregards the

² CATA was unable to supply data in time for this report. We will provide an amended report when these data arrive, presumably in early 2008.

transient commuters and freight haulers traveling through the Borough. Currently, there is no model or protocol for estimating emissions from these transitory commuters for State College Borough.

Another problem with our methodology is that it assumes that all registered vehicles are driven regularly. We disregard those commuters that walk, bike, or take a bus to work or school each day, which makes up a significant portion of the total population in the Borough. Figure 1 depicts the average means of commuting to work in State College, derived from the 2000 US Census. It is clear that our assumptions do not acknowledge these environmentally friendly commuters.

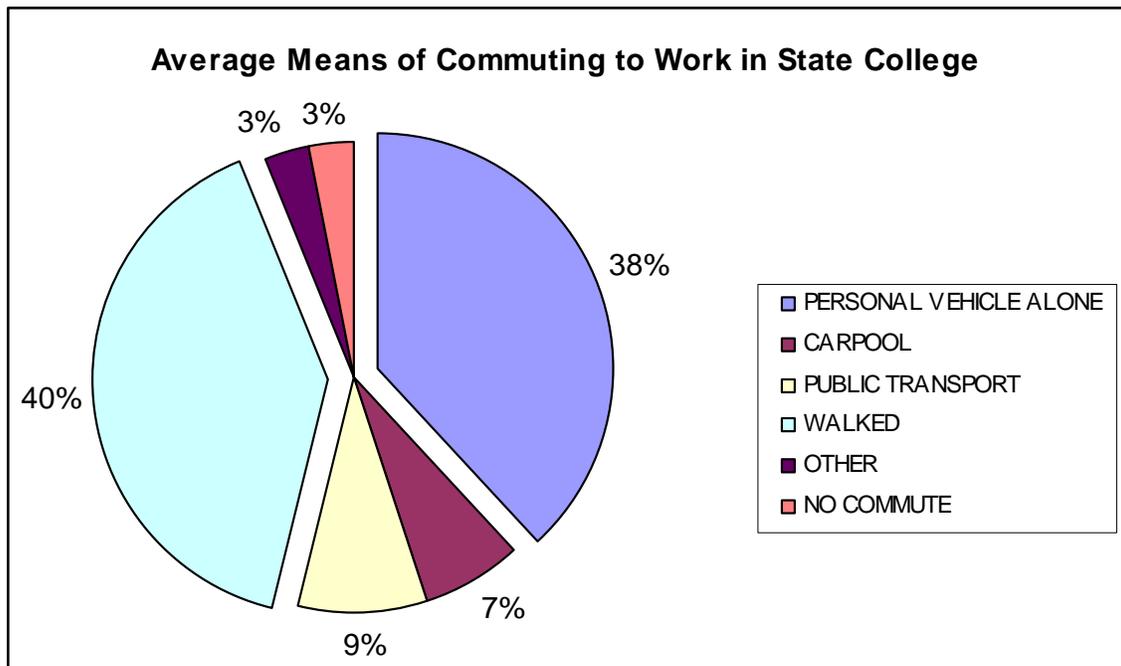


Figure 1. Average means of commuting to work in State College.

It is important to recognize that traffic is highly variable in State College. Future inventories need to acknowledge this factor. Traffic fluctuates year round because of student residence, graduation, special events (including football games, concerts and the Arts Fest), and holidays. We would expect to see variations in traffic patterns and associated GHG emissions that are not currently accounted for.

The accuracy of future GHG emissions estimates relies heavily on the availability of more robust data at the municipal scale. Huge improvements in accuracy and repeatability could be made if future inventories made concerted efforts to understand the transportation dynamics of State College.

These potential inaccuracies aside, we believe it is possible to draw general conclusions. As mentioned earlier, on the national scale, the transportation sector accounts for one third of GHG emissions. Our inventory found that transportation sector emissions account for nearly 37% of the Borough's total. This correspondence may suggest that, while

our inventory methods require improvement, the estimates may not be too far from the true value.

We suggest that the following data be obtained in future inventories to increase accuracy:

1. Actual number of registered vehicles in the Borough, and their types
2. Average miles traveled by each driver per day/week/month/year in the Borough OR fuel use by vehicle type in the Borough
3. Estimated emissions from transient vehicles (i.e., commuters, freight haulers)
4. Estimated vehicle use in the Borough

Comparison

Compared to Tompkins County, NY, State College Borough has far less emissions from transportation in total and per capita. State College’s total emissions equal less than a fifth of Tompkins’ total. However, Tompkins County has a much higher population, at 3.5 times that of State College (Table 4).

Table 4: State College and Tompkins County Emissions from Transportation (MTCO₂E)				
	State College	State College Per Capita	Tompkins County	Tompkins Per Capita
Total	119,265	4.42	645, 982	6.69

On-Site Fuel Sector

Overview

On-site fuel refers to fossil fuels burned for energy, consumed both in residences and commercial entities in State College Borough. Most residences and businesses in the Borough utilize on-site fuels for space and water heating. Most commonly, these fuels include utility natural gas, bottled/tank/LP gas, fuel oil, kerosene, and coal. In the Borough, one main utility distributor, Columbia Gas, supplies natural gas. For the other on-site fuels, numerous small distributors located in or near State College Borough supply these services. Below is list of primary distributors for each on-site fuel:

State College Borough On-Site Fuel Providers

- **Natural Gas** – Columbia Gas is the sole provider of utility gas to the Borough.
- **Bottled, Tank & LP Gas** – Propane companies in the area include Amerigas and Penn Fuel Propane in Bellefonte, and Suburban Propane and Columbia Propane in Pleasant Gap.
- **Fuel Oil** – Fuel oil companies in State College include C. Beard Oil, C.S. Myers & Son, Inc., Nittany Oil Company, and State Gas & Oil Company; there are several providers in the surrounding municipalities.
- **Coal** – There are no coal companies listed in the Borough, although there are many providers in surrounding municipalities. These providers include Nature's Cover in Bellefonte, King Coal Sales, Inc. in Philipsburg, and Watson Excavating & Coal Sales in Philipsburg.

As mentioned in previous sections, CO₂ is the primary GHG produced from the combustion of fossil fuels. Nationally, 82% of anthropogenic CO₂ emissions are the direct result of fossil fuel combustions. For the purposes of this inventory, we will focus on the emission of this gas.

Methodology

As mentioned, Columbia Gas is the sole provider of natural gas to the State College Borough. Columbia Gas supplied monthly utility gas consumption data for the year 2004. Data were supplied for both the entire Borough and the Penn State University Park campus. By subtracting the Penn State usage from the total location supply, we isolated State College Borough figures.

Data on residential fuel consumption is not available for State College Borough because many of the other on-site fuels come from small, unregulated suppliers. As a result, we used proxy methods to estimate consumption of the other fuel types. We focused only on

residential fuel use, as most of State College is residences and there are no large commercial industries based in the Borough. The proxy methodology duplicated the methods used by Knuth et al. (2005). These are also the methods used by The Pennsylvania Department of Environmental Protection for estimating residential energy consumption.

We obtained data from the United States Energy Information Administration (EIA, 2004b), which reports Pennsylvania residential consumption by fuel type. Next, we divided the consumption per fuel type by the number of Pennsylvania homes using that type of heating fuel as estimated by the US Census. To scale this consumption down to the Borough level, we multiplied Pennsylvania fuel consumption per home by the number of homes in the Borough of State College that use each particular fuel type. Since Census data were not explicitly available for the year 2004, we adjusted the number of households using each fuel type per capita by applying population estimates from 2004 and 2006.

After determining Borough consumption for each fossil fuel, we converted the fuel consumption figures into British Thermal Units (BTUs) following methods outlined by Steuer (2004). To calculate the total CO₂ emissions for the on-site fuel use sector, we multiplied the total consumption figures (in BTUs) by each fuel’s carbon content and proportional oxidization to CO₂, and then converted to MTCO₂E. For a detailed description of the methodology used for this sector, see Appendix D.

Results

Utility gas appears to contribute the most to State College Borough’s GHG emissions from on-site fuels (Table 5).

Table 5: Borough Emissions by Fuel Type in MTCO₂E					
	Utility Gas	Bottled, Tank, or LP Gas	Fuel Oil, Kerosene, etc.	Coal or Coke	Total
2004	80,919	1,938	18,053	76	100,986

Discussion

As noted, natural gas is the only on-site fuel with available localized data. The proxy estimations we employed uses per household consumption at the State level, scaled by the number of households in the Borough. This method, much like similar scaling tactics used in this report, is used widely but assumes that on-site fuel use is the same in all municipalities, disregarding possible regional variation. The lack of data for fuel oil, kerosene, coal, and LP gas identifies the need for a better reporting system regarding fossil fuel sales and/or consumption. On the supply side, government could mandate sales reports targeting point of delivery. On the demand side, the Borough could survey residents’ consumption periodically to gain a better understanding of household use of on-site fuels.

Despite this uncertainty, we conclude that the on-site fuels sector is responsible for approximately 31% of total GHGs emitted from State College Borough, which equals emissions from the electricity sector. In general, we would expect emissions from electricity to exceed those of on-site fuels. This parity suggests that a large proportion of housing units use natural gas and other on-site fuels instead of electric heat. It also suggests that air conditioning is not important in many State College residences. These heating and cooling patterns could be expected to widen since Allegheny Power will be increasing electricity prices by perhaps 40% in December 2008. With accompanying increases of on-site fuel consumption for home heating, we stress the importance of improving the understanding of electricity and on-site fuel consumption in State College Borough.

Comparison

Compared to Tompkins County, NY, State College Borough has less total emissions from on-site fuels, but more than three times the per capita emissions (Table 6). The former difference is attributable to Tompkins County’s higher population, which is 3.5 times that of State College.

Table 6: State College and Tompkins County Emissions from On-site Fuels (MTCO₂E)				
	State College	State College Per Capita	Tompkins County	Tompkins Per Capita
Total	100,986	3.75	116,315	1.21

Waste Sector

Solid Waste Overview

Favorable conditions for bacteria growth in landfills lead to an increase in methane emissions. Steuer (2004) explains:

“The anaerobic decomposition of solid waste in landfills produces “biogas,” which consists of both CO₂ and CH₄ (EIP, 1999, 5.2-1). The CO₂ constituent of biogas results primarily from the breakdown of organics from biomass sources. Biomass sources draw CO₂ from the atmosphere, through photosynthesis and return CO₂ to the atmosphere during decomposition. Because fluxes into and out of the surface are balanced, CO₂ generated at landfills is not counted as a GHG emission.”

Following Steuer, we will disregard CO₂ emissions and assume that they are simply part of the natural carbon cycle. The primary GHG that we will inspect is methane.

Nationally, only 2% of total GHG emissions can be attributed to the solid and liquid waste sectors. That said, landfills account for nearly 25% of all anthropogenic methane emissions. Although we expect emissions from this sector to be small compared to electricity, transportation, and on-site fuels, it is still an important contributor to total GHGs from State College Borough.

Solid waste collected by State College Borough is carried by truck to Shade Township Landfill in Somerset County. Although the methane is generated in Somerset County, the people of State College are directly responsible for these emissions. The Somerset County facility actively captures methane, and does not incinerate any solid waste. Figures given here reflect gas that escapes methane capture.

Methodology

To calculate methane emissions from the Borough’s solid waste, we obtained tons of garbage collected by the Borough in 2004. Eric Brooks, State College Borough Operations Manager, supplied these data.

Next, we put these data through an equation adapted by Steuer (2004) from Clean Air-Cool Planet (CACP). This equation yields total CH₄ through the following procedure:

- 1) Convert tons of solid waste sent to landfill to metric tons (mton)
- 2) Multiply by the kilograms of CH₄ generated per mton waste
- 3) Account for landfill type (methane recovery = 13.12 kg CH₄/mton)
- 4) Convert kilograms of CH₄ to mtons of CH₄
- 5) Multiply by Global Warming Potential to convert from mtons of CH₄ to MTCO₂E (CH₄ GWP= 23)

For an in-depth description of this procedure, see Appendix E.

Results

Solid waste from State College Borough generates four and a half metric tons of carbon dioxide equivalent in the Somerset County landfill (Table 7).

Table 7: Emissions of State College from the Solid Waste Sector in MTCO₂E	
Year	Total
2004	4,535

Discussion

Our methods for calculating GHGs from landfilled solid waste used standard, accepted procedures. We did not need to scale data for this sector, so there is a higher level of certainty associated with these results over those found in other sections of this report. However, the methodology does make two assumptions that could degrade our result. The first is that Steuer’s equation assumes the same general emissions coefficient for every landfill type, which does not account for variability in landfill practices. Second, Steuer’s equation does not account for recycled waste. Recent inventories count recycled waste as an offset for landfilled waste emissions. Had this been offset been included, State College’s total emissions might have dropped significantly.

Comparison

Compared to Tompkins County, NY, State College Borough has higher total and per capita emissions from solid waste (Table 8). Although difference could be attributable to undocumented differences in methodology used for the Tompkins County Inventory, it is likely to be the result of Ithica’s tough recycling and disposal regulations.

Table 8: State College and Tompkins County Emissions from On-site Fuels (MTCO₂E)				
	State College	State College Per Capita	Tompkins County	Tompkins Per Capita
Total	4,535	0.17	-8,751	-0.09

Liquid Waste Overview

Primary emissions from wastewater treatment include CH_4 and N_2O , which respectively have 23 and 310 times the warming potential of CO_2 emissions. On the one hand, methane results naturally from the decay of organic material in anaerobic environments. When treated under aerobic conditions, however, methane is not an inevitable product of wastewater treatment. On the other hand, nitrous oxide occurs in both aerobic and anaerobic conditions due to nitrification and denitrification processes associated with sludge.

Both Penn State's wastewater treatment plant and the University Area Joint Authority (UAJA) treat liquid waste from State College Borough. The Penn State Wastewater Treatment Plant takes whatever portion of the Borough's waste it wants to treat and sends the remainder to UAJA. The nature of treatment differs between the two plants.

UAJA treats liquid waste aerobically, thereby negating methane emissions. Penn State treats wastewater anaerobically, but collects the methane and flares it, thus resulting in emissions of CO_2 . Therefore, we focus on N_2O emitted from both plants and on the CO_2 from flared methane at the Penn State wastewater treatment plant.

Methodology

To calculate N_2O emissions from wastewater, we first obtained total wastewater flow data from each plant for 2004. Steve Weyant of the Office of the Physical Plant supplied data for the Penn State wastewater treatment plant influent flow; data were segregated by origin. Todd Alitz supplied UAJA's quarterly wastewater flows per 2004 Borough contract.

Using an equation adapted by Steuer (2007) from the Emissions Inventory Improvement Program (EIIP), we calculated nitrous oxide emissions by following these simple steps:

- 1) Assume .0017kg protein per gallon waste, and that protein is 16% nitrogen
- 2) Convert kg nitrogen to kg N_2O
- 3) Convert kg N_2O to mtons N_2O
- 4) Multiply by Global Warming Potential to convert from mtons of N_2O to MTCO_2E (N_2O GWP= 310)

To calculate CO_2 emissions from flared methane at the Penn State wastewater treatment plant, we obtained total cubic feet of flared methane gas from Steve Weyandt. Unlike the flow data, gas collection data were not segregated between the Penn State campus and State College Borough. Upon a suggestion by Steuer (2007), we assumed that approximately 40% of wastewater treated by Penn State originated in State College Borough. Using an equation adapted by Steuer (2007), we calculated CO_2 emissions from flared methane following these simple procedures:

- 1) Convert mcf of flared CH_4 to lbs of CH_4
- 2) Convert lbs of CH_4 to tons of CH_4

- 3) Convert tons of flared CH₄ to tons of CO₂
- 4) Convert tons of CO₂ to mtons of CO₂

For detailed calculation, see Appendix E

Results

We determined total GHG emissions from wastewater to be approximately 314 MTCO₂E (Table 9), with most of those emissions coming from N₂O and not methane.

Table 9: Emissions of State College from the Liquid Waste Sector in MTCO₂E			
Year	From Flared CH₄	From N₂O	Total
2004	0.70	313	313.70

Discussion

Like the solid waste sector, liquid waste data were available at the municipal scale, so these results are more certain than the electricity, transportation, and on-site fuel estimates. Sources of error in the liquid waste sector stem from the assumptions made by Steuer’s equations. Although these procedures are widely used and accepted, they do not account for the variability in wastewater treatment plant facilities.

Overall, the waste sector accounts for only 1% of total GHG emissions from State College Borough. This estimate is believable when compared to the 2% contribution of waste to national GHG emissions. Because of the availability of robust data at the municipal level, there are few ways to improve the inventory methods utilized in this sector. The main way to improve inventory accuracy is to customize calculations to State College Borough’s facilities and to obtain precise quantities in the Borough-University split of liquid wastes. Given the small contribution of waste to Borough GHG emissions, such an effort is not justifiable.

Comparison

Tompkins County, NY did not include liquid waste in their 1998 GHG assessment, citing that they had no control over mitigation in this sector. Therefore, no comparison is possible.

Synthetic Chemical Sector

Overview

State College Borough hosts two activities that involve synthetic chemicals and emit greenhouse gases: synthetic fertilizer application and refrigerant use. Given the difficulty involved in obtaining accurate data, refrigerants were not included in this inventory, which is standard procedure for all local and regional GHG inventories.

Synthetic fertilizers directly release N_2O into the atmosphere through nitrification/denitrification processes and indirectly through volatilization (Steuer, 2004). Main venues for synthetic fertilizer application within State College Borough include the twelve Borough parks and the Centre Hills Country Club. Fertilizer applied at golf courses far exceeds the amount used on regular lawns. Homeowners also use fertilizers, but this source of GHG emissions was not addressed in our inventory due to time constraints and the logistics of gathering this type of data. Again, this is standard procedure for local GHG inventories.

Methodology

The first step in calculating N_2O emissions from synthetic fertilizer use is to obtain data regarding total annual fertilizer use. It is important to note the percentage of nitrogen that the fertilizer contains. This information can be found on the label of most fertilizers in the N-P-K (nitrogen, phosphorous, potassium) ratio. Data are often given as pounds of fertilizer per unit area, in which case it is necessary to know the dimensions of the fertilized area.

To obtain the needed data, we contacted Greg Roth, Center County Parks Supervisor. He reported that in 2004, the level of fertilizer use was 0.5 lbs per 1000 ft². He also reported that there are 49.5 acres of park lawns in the Borough.

For information on fertilizer use at Center Hills Country Club, we contacted groundskeeper Gabe Menna. Menna reported that for the year 2004, approximately 4 lbs of nitrogen were applied per 1000 ft². This is 20 times the amount used on Borough park lawns. Center Hills Country Club fertilizes 75 acres of turf within Borough limits.

Roughly 10% of Nitrogen from fertilizers volatilizes into NH_3 and NO_x (IPCC, 1997). The remaining 90% undergoes the nitrification/denitrification process, which emits N_2O directly to the atmosphere. Of the unvolatilized nitrogen, an additional 30% leeches into groundwater where it feeds biota and becomes indirect N_2O emissions (EIIP, 1999).

With this information, we made calculations using methods specified in the 1999 GHG Emission Inventory Improvement Program (EIIP, 1999), utilizing an equation developed by Steuer (2004) for the Penn State inventory. This equation includes all emissions resulting from volatilized and unvolatilized nitrogen. For details, see Appendix F.

Results

The annual total emissions from the application of synthetic fertilizer to Borough parks and Centre Hills Country Club are 54 MTCO₂E (Table 10).

Table 10: Emissions of State College Borough from Synthetic Fertilizers in MTCO₂E	
Year	Total
2004	54

Discussion

State College Borough does not have significant amounts of land that are fertilized. Consequently, an extremely small proportion of greenhouse gas emissions (<1%) result from synthetic fertilizer application. However, this does not suggest that it is unimportant to monitor use of synthetic fertilizers in the Borough. Synthetic fertilizers can have environmental consequences other than greenhouse gas emissions, such as nutrient loading and eutrophication in water sources. Also, the process of making synthetic fertilizer requires the use of fossil fuels, mostly natural gas, which results in more greenhouse gas emissions than calculated in this inventory (Rich, 2006).

The procedure of data collection in this sector has highlighted the need for accurate record keeping concerning synthetic chemicals. Refrigerants were not included in the inventory, yet these gases (hydrofluorocarbons) can have a warming effect up to 3,000 times stronger than carbon dioxide (EPA, 2006). Data on refrigerants are difficult to obtain, however, due to suppliers for this region being widely scattered. Before mitigation strategies can be effective in this sector, policies requiring accurate sales and use of these chemicals are essential. Additionally, the inventory of emissions from fertilizer use could be far more accurate if better records were kept. For example, we were not able to estimate emissions from private use of fertilizer, which would be necessary before a mitigation strategy for this sector could be applied. As part of an overall “green” strategy for the Borough, future efforts in the synthetic chemicals sector should center on improved record-keeping methods. However, due to the negligible amount of GHGs emitted by this sector, GHG mitigation efforts should primarily focus on the other sectors in this inventory.

Comparison

Tompkins County, NY did not include synthetic chemicals in their 1998 GHG assessment, therefore precluding a comparison for this sector.

Overall Inventory Results

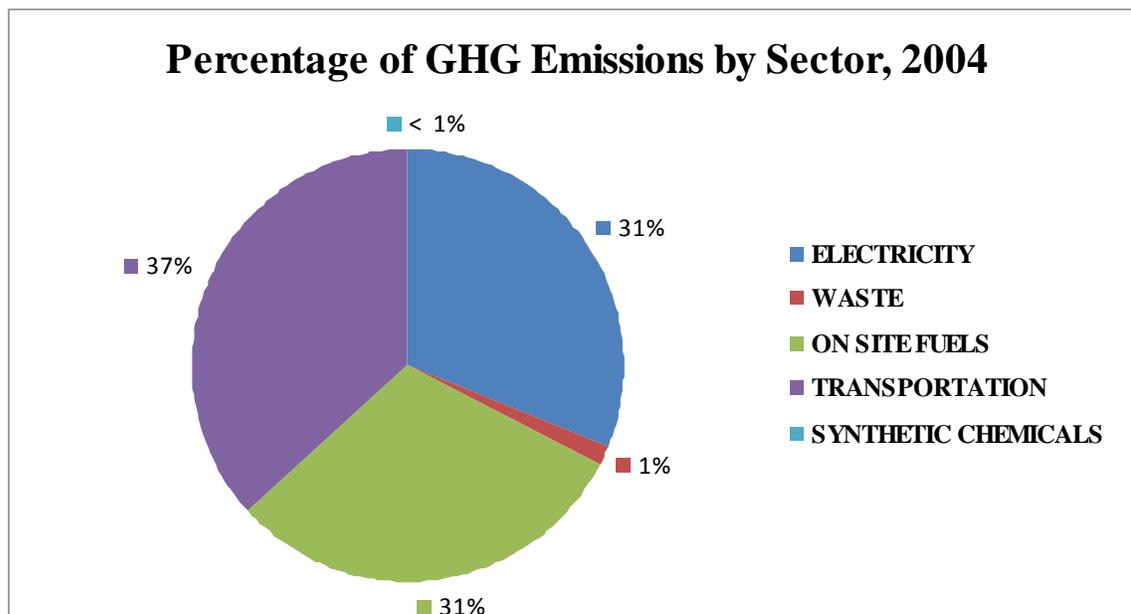


Figure 2. Overall results of the State College Borough greenhouse gas emissions inventory.

The sector with highest GHG emissions was transportation, followed in order by electricity and on-site fuels, waste, and synthetic chemicals (Figure 2). Given the great uncertainty in the data, the top three sectors should be considered equivalent in their emissions, and—all things being equal—mitigation actions should focus equally on these three sectors. Table 11 depicts overall sector totals for State College Borough for 2004.

Table 11: Sector Totals in MTCO ₂ E for the Year 2004					
Electricity	Transportation	On-Site Fuels	Waste	Synthetic Chemicals	Total
101,229	119,245	100,988	4,848	54	326,452

Conclusions

The problems associated with global warming can be difficult to grasp given the vast scale of the problem and the uncertainty involved in the science. Despite these problems, it is clear that the argument is no longer *if* drastic consequences will arise or not, but *which* drastic consequences will arise and *when* will they arise. Thus, immediate action seems not only to be logical, but also necessary for the well being of Earth's natural and human systems.

The State College Borough inventory is an important first step in taking action at the local level to mitigate climate change, but without further action, the time invested in this inventory will have been in vain. Moreover, the inventory process is far from complete or certain.; this process must be refined and recalculated periodically.

As explained in each sector, obtaining accurate local-level data was our biggest problem. We often needed to use per capita scaling or other estimation techniques to compute emissions for State College Borough. Ironically, those sectors with good local data—waste and synthetic chemicals—are not significant sources of GHGs. Of the important emissions sectors, both electricity and on-site fuels data are available from the providers, but these private companies are hesitant to provide those data. Only transportation data are difficult to measure and not readily available; better methods for estimating local emissions from the transportation sector are essential.

In addition, the inventory was hampered by a short data span. It is important to identify trends in emissions and isolate factors responsible for variation between years. The Kyoto Protocol calls for reductions below 1990 levels. If the Borough wants to become Kyoto compliant, as many environmentally conscious communities are, then it is necessary to know 1990 emissions levels. Currently, with only the 2004 inventory presented here, this is not possible—even through robust backcasting methodologies.

Therefore, to track GHG emissions over time and to determine the effectiveness of actions taken to mitigate GHG emissions, we recommend the Borough:

- Initiates efforts to collect and archive electricity use and on-site fuel consumption
- Works with faculty and students at Penn State to develop effective methods for estimating emissions from transportation
- Institutes annual GHG inventories

References

- AAG (2003). *Global Change in Local Places: Estimating, Understanding, and Reducing Greenhouse Gases*, Association of American Geographers Global Change in Local Places Research Team, Eds. Cambridge University Press: Cambridge, England.
- Allegheny Energy (2006). *About Us*. Accessed November 2006 at <<http://www.alleghenyenergy.com/Newsroom/AboutUs.asp>>.
- BTS (2006). *Fuel Consumption by Mode of Transportation*. Bureau of Transportation Statistics. U.S. Department of Transportation. Accessed 1 December 2007 at <http://www.bts.gov/publications/national_transportation_statistics/html/table_04_05.html>.
- DeCicco J., and Fung F. (2004). Environmental Defense. *Global Warming on the Road*. Accessed 1 December 2007 at <http://www.environmentaldefense.org/documents/5301_Globalwarmingontheroad.pdf>.
- Detrick L., Knuth S., Taiclet J., and White J. (2005). *Centre County Community Energy Project Phase I Report*. Accessed 10 December 2006 at <<http://cira.psu.edu/Sara%20Knuth/Final%20Report%20%20Phase%20I%20%28Revised%207-06%29.pdf>>.
- EIA (2001). *Emissions of Greenhouse Gases in the United States 2000*. Report No. EIA/DOE 0573(2000); Washington, DC: Energy Information Administration, U.S. Department of Energy. Accessed 1 January 2008 at <<http://www.eia.doe.gov/oiaf/1605/1605a.html#links>>.
- _____ (2004a). *Greenhouse Gases, Climate Change, and Energy*. Energy Information Administration. Accessed 9 December 2006 at <<http://www.eia.doe.gov/oiaf/1605/ggcebro/chapter1.html>>.
- _____ (2004b). Energy Information Administration. *Residential Sector Energy Consumption Estimates, 2004*. Accessed 10 October 2007 at <http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_bt_u_res.html>.
- EIIP (1999). *Estimating Greenhouse Gas Emissions, Volume VIII* (Washington, DC, Greenhouse Gas Committee, Emissions Inventory Improvement Program and United States Environmental Protection Agency). Accessed 2 December 2007 at <<http://www.epa.gov/ttn/chief/eiip/techreport/volume08/index.html>>.
- EPA (2007). *Emissions Facts: Average Carbon Dioxide Emissions Resulting From Gasoline and Diesel Fuel*. Environmental Protection Agency. Accessed 1 December 2007 at <<http://www.epa.gov/otaq/climate/420f05001.htm>>.

- _____ (2006a). *Electricity from Coal*. Environmental Protection Agency. Accessed 12 December 2006 at <<http://www.epa.gov/cleanenergy/coal.htm>>.
- _____ (2006c). *Methane*. Environmental Protection Agency. Accessed 8 December 2006 at <<http://www.epa.gov/methane/>>.
- _____ (2006d). *Nitrous Oxide: Sources and Emissions*. 19 Oct. 2006. Accessed 9 December 2006 at <<http://www.epa.gov/nitrousoxide/sources.html>>.
- _____ (2005). *Global Warming: Resource Center: Publications: GHG Emissions: U.S. Emissions Inventory 2005*. Environmental Protection Agency. Accessed 9 Dec. 2006 at <<http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html>>
- _____ (2001). *U.S. Inventory of Greenhouse Gas Emissions and Sinks, 1990-1999*. Report No. EPA 236-R-01-001; Washington, DC: Office of Atmospheric Programs, U.S. Environmental Protection Agency. <http://www.epa.gov/globalwarming/publications/emissions/us2001/index.html>.
- Fay, G. (1998). *Greenhouse Gas Emissions Inventory Report: Tompkins County, NY*. International Council for Local Environmental Initiatives. Accessed 16 December 2007 at <http://www.co.tompkins.ny.us/emc/docs/5_ccp_emissions_inventory.pdf>.
- FHWA (2006). *2004 Highway Statistics*. Federal Highway Administration. U.S. Department of Transportation. Accessed 1 December 2007 at <<http://www.fhwa.dot.gov/policy/ohim/hs04/index.htm>>.
- Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz, and R. Van Dorland (2007). Changes in Atmospheric Constituents and in Radiative Forcing. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds. Cambridge University Press: Cambridge, U.K., pp. 129-234.
- Hess, C.R. (2007). Planning Director, Borough of State College, *Personal communication*, September.
- Houghton, J. T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P. J., and Xiaosu, D., Eds. (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press: Cambridge, U.K.
- IPCC (2001). *Glossary of Terms Used in the IPCC Third Assessment Report*. Intergovernmental Panel on Climate Change. <<http://www.ipcc.ch/pub/syrgloss.pdf>>.

- _____. (1997). *Revised 1996 Guidelines for National Greenhouse Gas Inventories: Workbook*, Intergovernmental Panel on Climate Change, United Nations Environment Program, Organization for Economic Co-Operation and Development, International Energy Agency. Accessed available online at <<http://www.ipcc.ch/pub/guide.htm>>
- Kearney, T.J. (2006). General Manager, Operations, Allegheny Power Company, *Personal communication*, October-November.
- Knuth, S.E. (2006). Ph.D. student, University of California. *Personal communication*, November 7.
- _____, B. Nagle, C. Steuer, and B. Yarnal (2007). Universities and Climate Change Mitigation: Advancing Grassroots Climate Policy in the US. *Local Environment*, 12, 485-504.
- _____, J. White, J. Taiclet, and L. Detrick (2005). Centre County Community Energy Project—Phase I Report: Baseline Energy Consumption in Centre County. Center for Integrated Regional Assessment, The Pennsylvania State University. Accessed on 1 January 2008 at <<http://www.cira.psu.edu/Past%20Projects.htm>>.
- Krinks, K.L. (2006). Assistant Director of Housing Assignment Operations, Pennsylvania State University, *Personal communication*, November 15.
- McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., and White, K.S., Eds. (2001). *Climate Change 2001: Impacts, Adaptation & Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press: Cambridge, U.K.
- Menna, G. (2006). Groundskeeper, Centre Hills Country Club, *Personal communication*, November.
- PJM (2004). *PJM Regional Average Disclosure Label for 2004: Electricity facts*. Accessed 1 January 2008 at <http://www.dcpsc.org/pdf_files/customerchoice/RatesAndStatistics/pmjfuelmix2004.pdf>.
- PUC (2002). *Electric Power Outlook For Pennsylvania 2001-2006*. (Harrisburg, PA, Pennsylvania Public Utility Commission, Bureau of Conservation, Economics & Energy Planning). Accessed 1 January 2008 at <http://www.puc.state.pa.us/general/publications_reports/pdf/EPO_2002.pdf>.
- _____. (2004). *Electric Power Outlook For Pennsylvania 2003-2008* (Harrisburg, PA, Pennsylvania Public Utility Commission, Bureau of Conservation, Economics & Energy Planning). Accessed 1 January 2008 at <http://www.puc.state.pa.us/general/publications_reports/pdf/EPO_2004.pdf>.

- Rich, D.K. (2006). *The Case Against Synthetic Fertilizers*, San Francisco Chronicle, January 14. Accessed 1 January 2008 at < <http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2006/01/14/HOG71GLP6A1.DTL>>.
- Roth, G. (2006). Supervisor, Centre County Parks Commission, *Personal Communication*, October 13.
- Rose, A. (2003). Greenhouse Gas Mitigation Plan: An Overview. *Penn State/Dickinson Environmental Law Review*, **2003**, 12, 153-71.
- _____, Neff, R., Yarnal, B., and Greenberg, H. (2005). A Greenhouse Gas Emissions Inventory for Pennsylvania; *Journal of the Air and Waste Management Association*, 55, 1122-1133.
- _____, A., and Zhang, Z.X. (2004). Intraregional Burden-Sharing of Greenhouse Gas Mitigation in the United States; *Mitigation and Adaptation Strategies for Global Change*, 9, 477-500.
- Steuer, C.J. (2004). *A Greenhouse Gas Emissions Inventory and Projection for the University Park Campus of the Pennsylvania State University*. Unpublished M.S. thesis, The Pennsylvania State University, University Park. Accessed 1 January 2008 at <<http://www.cira.psu.edu/Past%20Projects.htm>>.
- _____. (2007). Associate, ICF International, *Personal Communication*, November 30.
- U.S. Census Bureau (2007). *U.S. Fact Finder*. Accessed 10 September 2007 at <<http://factfinder.census.gov>>.

Appendix A: Calculation of Population Data

This Appendix expands upon the calculation of population data for use in several sectors of this inventory.

To calculate Borough Population per zip code, the following steps were taken:

- 1) Contacted Carl Hess, Borough Planning director for method proposal
- 2) Hess suggested segregating Borough population by Census Tracts (CT), which are subsequently segregated by zip codes within State College. These Tracts are:
 - a. 16801- CTs 120, 124, 125, 126, 127 and 128
 - b. 16803- CT 123
 - c. 16802 (campus)-CTs 121 and 122
- 3) Population for each CT was found on the US Census 2000 Website
- 4) To estimate population for the year 2004, we calculated the percentage of population change in Borough population. Again, Hess supplied data
 - a. change was found be 1.2%; CT populations were increased by 1.2% to estimate 2004 population
- 5) To isolate population from census tracts for the Borough without Penn State, CTs from 16801 and 16803 were added. 16802 was omitted.
 - a. Calculation result: 26,963 people—This was the value used in per capita scaling
 - i. 25,118 in zip 16801
 - ii. 1,845 in zip 16803

To calculate per capita electrical per zip code in the electrical sector, we had to estimate population for the year 2004. To do this, the following steps were taken:

- 1) Obtained Centre County population 2004 from county planning Website
- 2) Calculated percent population change in the county from 2000-2004
 - a. Change was found to be 3.1%. Zip code populations were increased by 3.1% to estimate 2004 population. The results:
 - i. 41,264 in Zip 16803
 - ii. 20,395 in Zip 16801

Appendix B: Calculation of Electricity Sector Data

To calculate emissions from electricity consumption, the following steps were taken:

- 1) Averaged together all duplicated months supplied by Allegheny Power to normalized 18 month data span into 1 year. (i.e., $(\text{month1} + \text{month2})/2 = \text{average}$)
- 2) Totaled monthly consumption data for sector in each zip code in the Borough
 - a. Omitted the following sectors, since they do not occur in State College
 - i. Large commercial, large industrial
- 3) Divided total annual usage in each zip code by 2004 population (Appendix A) to get per capita
- 4) Multiplied per capita usage by the number to Borough residents living in corresponding zip code (Appendix A) to get kWh consumed by the Borough
- 5) Multiplied per capita usage by the annual emissions output rate for coal fired electricity production (supplied by PJM) to get lbs of CO₂ per kWh consumed
- 6) Converted lbs of CO₂ to MTCO₂E by dividing by the number of lbs in a metric ton; 2205

Resulting Equation:

MTCO₂E emitted =
 $((\text{kWh consumed electricity per sector})/(\text{zip code pop.})) * (\text{Borough pop in zip}) * (\text{lbs CO}_2/\text{kWh}) / (2205)$

Appendix C: Calculation of Transportation Sector Data

To calculate emissions from transportation, the following steps were taken:

- 1) Obtained number of cars registered per vehicle type to the State of PA, and the nation from Federal Highway Administration's Website
- 2) Obtained national amount of fuel consumed per vehicles type from the Bureau of Transportation Statistics Website (2006)
- 3) Synchronized car types between the two data into categories so that data can be compared
 - a. Collapsed into 3 categories: Automobile (Cars, motorcycles, SUVs, pickup trucks), Truck (Heavy diesel fueled vehicles), and Bus
- 4) Divided total fuel consumed per vehicle type by number of registered vehicles to yield gallons of fuel consumed per vehicle by type
- 5) Estimated number of vehicles by type registered in the Borough
 - a. Divided number of vehicles by type in PA by PA population to get per capita
 - b. Multiplied by Borough population (Appendix A)
- 6) Multiplied estimated number of vehicles in Borough by fuel consumed per vehicle from Step 4 to calculate gallons of fuel consumed from transportation in the Borough
- 7) Multiplied gallons of fuel consumed in Borough by lbs of CO₂ per gallon burned, as estimated by the EPA
 - a. Diesel = 19.4 lbs CO₂ per gallon burned
 - b. Gasoline = 22.2 lbs CO₂ per gallon burned
- 8) Converted lbs of CO₂ to MTCO₂E by dividing by the number of lbs in a metric ton; 2205

Resulting Equation:

MTCO₂E emitted =
((gallons of fuel consumed by vehicle type in US)/(# vehicles in US))*(# vehicles in Borough)*(lbs CO₂/gallon burned)/(2205)

Appendix D: Calculation of On-site Fuels Sector Data

To calculate emissions from on-site fuel consumption, the following steps were taken:

- 1) Obtained natural gas consumption data for Borough and Penn State, subtracted Penn State to isolate Borough total
- 2) To acquire data for the other fuel types used source data from EIA reports on PA residential consumption per household.
- 3) Obtained number of houses using each fuel type in the Borough from US census 2000 & 2006
 - a. Calculated percent annual increase in number of houses using each fuel type per to estimate number of houses using each fuel type in 2004.
 - i. Calculated 4.3% annual increase
- 4) Multiplied number houses in the Borough using each fuel type by average usage per house from EIA to yield total fuel consumed in the Borough per fuel type.
- 5) Converted from volume of gas to BTU using EIA conversion Factors
- 6) Multiplied by the carbon content of each fuel type, from Steuer and/or EIA
- 7) Converted lbs carbon to lbs CO₂ (44lbs CO₂/12 lbs C)
- 8) Converted lbs of CO₂ to MTCO₂E by dividing by the number of lbs in a metric ton; 2205

Steuer's Equations, by fuel type:

Coal [sic]:

Equation B.2 CO₂ emissions coefficient calculation for coal combustion

$$\frac{24.82 \text{ mBtu}}{\text{mcf Natural Gas}} \times \frac{56 \text{ lbs C}}{\text{mmBtu}} \times 99.5\% (\% \text{ oxidized}) \times \frac{1 \text{ ton C}}{2000 \text{ lbs C}} \times \frac{0.9072 \text{ mtons C}}{\text{ton C}} \times \frac{3.67 \text{ mtons CO}_2}{\text{mton C}} \quad \text{B.2}$$

Natural Gas:

Equation B.3 CO₂ emissions coefficient calculation for natural gas combustion

$$\frac{1.031 \text{ mBtu}}{\text{mcf Natural Gas}} \times \frac{31.9 \text{ lbs C}}{\text{mmBtu}} \times 99.5\% (\% \text{ oxidized}) \times \frac{1 \text{ ton C}}{2000 \text{ lbs C}} \times \frac{0.9072 \text{ mtons C}}{\text{ton C}} \times \frac{3.67 \text{ mtons CO}_2}{\text{mton C}} \quad \text{B.3}$$

Fuel Oil:Equation B.4 CO₂ emissions coefficient calculation for fuel oil 1-4 combustion

$$\frac{5.825 \text{ mBtu}}{\text{barrel Fuel Oil}} \times \frac{44 \text{ lbs C}}{\text{mmBtu}} \times 99\% (\% \text{ oxidized}) \times \frac{1 \text{ ton C}}{2000 \text{ lbs C}} \times \frac{0.9072 \text{ mtons C}}{\text{ton C}} \times \frac{3.67 \text{ mtons CO}_2}{\text{mton C}} \quad \text{B.4}$$

LP Gas:Equation B.7 CO₂ emissions coefficient calculation for propane combustion

$$\frac{4.011 \text{ mBtu}}{\text{barrel Propane}} \times \frac{37.8 \text{ lbs C}}{\text{mmBtu}} \times 99\% (\% \text{ oxidized}) \times \frac{1 \text{ ton C}}{2000 \text{ lbs C}} \times \frac{0.9072 \text{ mtons C}}{\text{ton C}} \times \frac{3.67 \text{ mtons CO}_2}{\text{mton C}} \quad \text{B.7}$$

Appendix E: Calculation of Waste Sector Data

To calculate emissions from waste, the following steps were taken:

Solid Waste

- 1) Obtained tons of solid Waste data from Eric Brooks, State College Operations Manager
- 2) To calculate emissions from landfilled solid waste, we explicitly followed the methodology of Steuer (2004). His equation is represented below.

Equation B.41 CH₄ emissions coefficient for landfills that captures CH₄

$$\frac{0.9072 \text{ mtons solid waste}}{\text{ton solid waste}} \times \frac{13.12 \text{ kg CH}_4}{\text{mton solid waste}} \times \frac{1 \text{ mton}}{1000 \text{ kg}} \times \frac{23 \text{ mtons CO}_2}{\text{mtons CH}_4} \quad \text{B.41}$$

Liquid Waste

CO₂ from flared methane:

- 1) Obtained gas collected by PSU's wastewater treatment plant from Steve Weyandt of OPP,
- 2) We explicitly followed the methodology of Steuer. His equation is represented below

Equation B.37 CO₂ emissions coefficient for flared CH₄

$$\frac{42.28 \text{ lbs CH}_4}{1 \text{ mcf}} \times \frac{1 \text{ ton CH}_4}{2000 \text{ lbs CH}_4} \times \frac{0.003 \text{ tons CO}_2}{\text{ton flared CH}_4} \times \frac{0.9072 \text{ mtons CO}_2}{\text{ton CO}_2} \quad \text{B.37}$$

N₂O:

- 1) Obtained annual wastewater flows attributable to the Borough from both Penn State and UAJA.
- 2) Used following procedure in calculating N₂O emissions, adapted from Steuer (2007) and the EIIP
 - a. Multiplied influent flow by .0017 to yield kg protein per gallon waste
 - b. Multiplied by .16, Since protein is 16% Nitrogen
 - c. Converted kg Nitrogen to kg N₂O-N (.01 kg N₂O-N/ kg N)
 - d. We explicitly followed suggest procedure from EIIP, as represented below

Step (5) Convert the Units to Metric Tons of Carbon Equivalent of N₂O

- To convert the units, perform the following calculations:
 - Divide kg of N₂O-N by 1000 to obtain metric tons of N₂O-N.
 - Multiply metric tons of N₂O-N by the mass ratio of N₂O to N (44/28) to obtain metric tons of N₂O.
 - Multiply metric tons of N₂O by the mass ratio of carbon to carbon dioxide (12/44) and by the global warming potential for N₂O (310) to obtain metric tons of carbon equivalent of N₂O.

$$\text{N}_2\text{O from wastewater (kg N}_2\text{O-N)} \div (1000 \text{ kg/metric ton}) \times (44/28) \times (12/44) \times 310 = \\ \text{N}_2\text{O from wastewater (metric tons N}_2\text{O)}$$

Appendix F: Calculations of Synthetic Chemical Sector Data

To calculate emissions from synthetic chemicals, the following steps were taken:

- 1) Obtained fertilizer data from Greg Roth, Center County Parks Supervisor, and Gabe Menna, Groundskeeper for the Center Hills Country Club
- 2) All calculations in this sector were performed following the methods outlined by Steuer (2004). The relevant formula is represented below

Equation B.54 N₂O emissions coefficient from synthetic fertilizer use

$$90\% (\% \text{ unvolatized}) \times \frac{0.0125 \text{ lbs N}_2\text{O} - \text{N}}{\text{lb N}}$$

$$\text{Direct Emissions} = 0.01125 \frac{\text{lbs N}_2\text{O} - \text{N}}{\text{lb N}}$$

$$\left[90\% (\% \text{ unvolatized}) \times 30\% (\% \text{ leached}) \times \frac{0.025 \text{ lbs N}_2\text{O} - \text{N}}{\text{lb N}} \right] + \left[10\% (\% \text{ volatized}) \times \frac{0.01 \text{ lbs N}_2\text{O} - \text{N}}{\text{lb N}} \right]$$

$$\text{Indirect Emissions} = 0.00775 \frac{\text{lbs N}_2\text{O} - \text{N}}{\text{lb N}} \quad \text{B. 54}$$

$$\left[0.01125 \frac{\text{lbs N}_2\text{O} - \text{N}}{\text{lb N}} + 0.00775 \frac{\text{lbs N}_2\text{O} - \text{N}}{\text{lb N}} \right] \times \frac{1.5714 \text{ lbs N}_2\text{O}}{\text{lb N}_2\text{O} - \text{N}} \times \frac{\text{ton N}_2\text{O}}{2000 \text{ lbs N}_2\text{O}} \times \frac{0.9072 \text{ mton N}_2\text{O}}{\text{ton N}_2\text{O}}$$

$$\times \frac{296 \text{ mton CO}_2}{\text{mton N}_2\text{O}}$$