Tracking and Reducing Greenhouse Gas Emissions at WPI

An Interactive Qualifying Project proposal to be submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Abstract

This report, as conducted at Worcester Polytechnic Institute, explored the carbon emissions directly produced as a result of on-campus activities. The purpose the inventory is to evaluate the current status at WPI and evaluate several possible options to reduce these emissions. This report will address the necessary background, methods, results, analysis and recommendations. With this report we hope to establish a precedent for yearly inventories aimed at reducing greenhouse gas emissions at WPI.

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Chapter 1: Introduction

Over the last few centuries the Earth has gone through some dramatic changes. However none of these changes have been as global and looming as the problem of global warming. Global warming is caused by the combustion of fossil fuels which trap the heat from the sun in the Earth's atmosphere slowly warming up the planet. Global warming is an especially important issue because the world, in particular the United States, is extremely dependent upon fossil fuels for our energy needs.

With each passing year, the Earth's population increases and more energy is needed to meet our growing needs. Few people realize that much of the electricity we use is generated in coal plants which produce huge amounts of greenhouse gases because coal is a very dirty fuel. Steps have been taken to use more nuclear and hydro power to offset the amount of coal used, but coal remains the primary fuel which is also unfortunate because eventually the global coal supply will be depleted.

All the anxiety over the Greenhouse effect has caused great discussion among important organizations, specifically the United Nations. In 1997 they drafted the Kyoto Protocol which sets emission reduction goals for all voluntary participants which for most are 5% below their 1990 levels (Convention on Climate Change 1997). Many problems arise with this because many countries have not done inventories and do not know their 1990 levels. Many under developed countries feel this is unfair because they are being forced to limit the use of cheap fuels which greatly aided other countries in becoming world powers, such as the United States and Great Britain. The protocol also lacks power because the United States did not ratify it yet but still emits the most greenhouse gases of any country. Even though the United States is not participating, there are smaller communities that are actively conducting their own inventories aimed at reducing emissions.

Worcester Polytechnic Institute is a small technical school of roughly 3,300 students located in Worcester, Massachusetts (Andrews 2004). Like every other campus and industry in the world WPI has problems with emitting excessive amounts of greenhouse gases especially through energy use. There would be several benefits to WPI for doing a greenhouse gas inventory which include a better reputation in the community and helping clean the environment. To the best of our knowledge no such inventory has ever taken place. Our report is going to be aimed at taking a look at these gases to find out how many WPI emits on a yearly basis. The more important goal is to set up a yearly inventorying system which could track these gases and automatically input them into a spreadsheet format. Lastly, our inventory would provide evidence for new policies at WPI aimed at reducing greenhouse gases.

Chapter 2: Background

The Greenhouse Effect is a world-wide issue that will not go away without the cooperation and hard work of every nation on Earth. For hundreds of years people used whatever fuels were most accessible. Unfortunately in years later we have found that these fuels emitted tons and tons of substances containing carbon into the atmosphere. Currently there are more fuels we can use that produce fewer of these harmful emissions. However the biggest sources of carbons are still the most widely used ones: coal, oil and natural gas. This section will look at the history of producing greenhouse gases, as well as the fuels that cause them. It will also show how the United States ranks in these emissions compared to the rest of the world and several steps people in ordinary homes can take to reduce their own greenhouse gas emissions.

2.1 Worldwide efforts to reduce greenhouse gases

In December of 1997 the United Nations signed into affect the Kyoto Protocol which, according to article 3, insists that participating countries lower their overall greenhouse gas emissions to an acceptable level. They propose this level as 5% below the 1990 levels, and they would like as many participants to reach this level by 2012 as possible. A greenhouse gas is defined as “a gas that contributes to the greenhouse effect by absorbing infrared radiation” (Greenhouse Emission 2006). The greenhouse effect is the gradual heating of the Earth due to certain gases in the atmosphere which insulate the sun’s rays.

Interestingly enough, the United States and Australia are the only two large industrialized countries that have signed the treaty but have not ratified it. Nearly every other industrialized country in the world has ratified it; all of Europe, all of South America, most of Asia and parts of Africa. It should also be noted that the United States, which contributes 25% of the total global greenhouse gas emissions, has not signed this Protocol but has taken steps to voluntarily reduce emissions. The organization also took the time to outline the gases that have the greatest impact on the Greenhouse Effect. These gases include carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O), Halocarbons (PFCs and HFCs) and sulfur hexafluoride (SF_6), but for our project we will be focusing exclusively on carbon emissions. We will only focus on carbon emissions because the sources of the other emissions are agriculture, livestock and refrigerants. WPI does no significant agricultural work and maintains no livestock so methane and nitrous oxide can be ignored. The coolant data maintained at WPI was not very thorough and did not contain any of the refrigerants outlined in the Clean-Air Cool Planet Emissions Calculator so these can be omitted as well. The Kyoto Protocol also gives each of the different gases a Global Warming Potential (GWP) as a way of showing how harmful they are to the atmosphere relative to carbon dioxide which has a GWP value of 1. The main source of these harmful carbon emissions arises from burning fossil fuels such as oil, coal and gasoline.

2.2 Greenhouse Gas Emissions

For many decades people have haphazardly burned fossil fuels without thinking about the damage being done to the environment. As time has gone on, scientists have performed studies and believe that the Earth is slowly heating up due to increased amounts of greenhouse gases in the atmosphere. These gases act like a blanket and trap the heat from the sun as it is reflected off the Earth. Figure 1 below helps to illustrate the rate that the temperature of the Earth has been increasing.

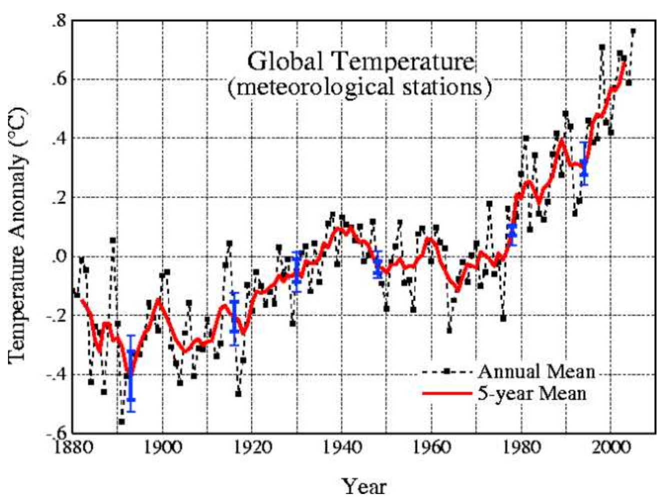


Figure 1: Global Temperature Trends (Sato 2006)

Industry is the largest supplier of greenhouse gases and consumes the most energy, consuming 41% of the total global energy supply in 1995 (Price 1998). In the past coal was a favorite energy source used for both heating and powering heavy machinery. Today coal is still widely used primarily in electricity plants even though more effective electric generation sources have emerged such as oil and nuclear power.

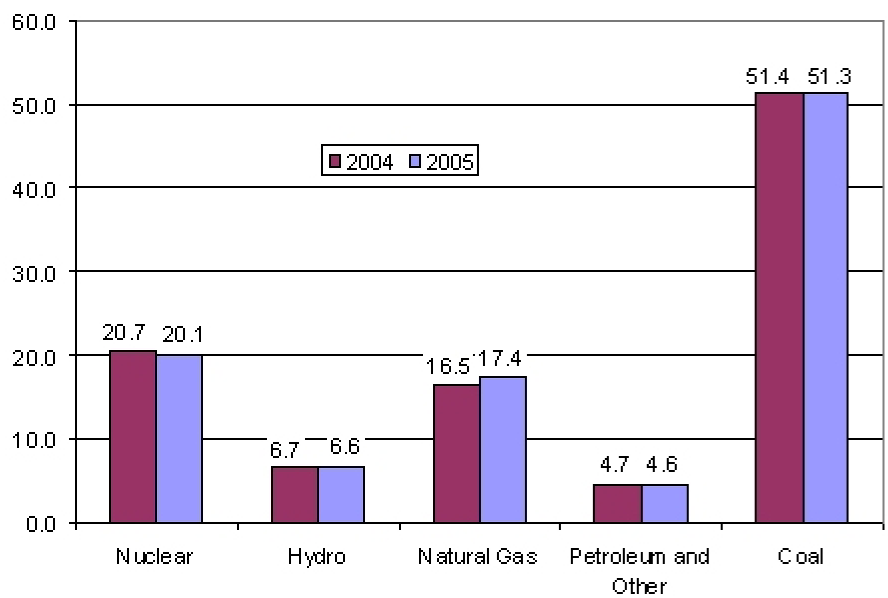


Figure 2: Percent Composition of Fuels That Generate Electricity (Freme 2006)

Industry is not the only cause though. People emit, or are responsible for, enormous amounts of greenhouse gases in their everyday activities. Cars and trucks are responsible for the release of large amounts of carbon dioxide and carbon monoxide (U.S. Army 2005). Few people realize that large amounts of electricity are produced in coal plants. Due to this lack of knowledge many people do not take proper care to minimize their electricity use: lights are left on, computers are left running overnight, televisions are not shutoff. If people took more care to turn electric devices off when they are not in use the amount of greenhouse gases would greatly be reduced.

2.2.1 Greenhouse Emissions for the World at Large

It is very difficult to compare energy usage and greenhouse gas emissions between the United States and the rest of the world because most of the world is not as developed as the United States. Many countries in Africa, Asia and South America have little to no electricity usage and hardly any vehicles. In the United States however there is a great deal of emphasis placed on having vehicles and using more and more electricity. Greenhouse gas emissions are a problem all throughout the world because the majority of automobiles are still gasoline or diesel powered and renewable energy sources are still taking a backseat to oil.

One study has found that global electricity usage increased by about 2.5% a year between 1971 and 1990; 5.31×10^{14} kilowatt hours in 1971 to 8.53×10^{14} kilowatt hours in 1990, which means the global electricity use almost doubled in 20 years (Price 1998). The authors did indicate that this trend did start to plateau several years later, but the problem remains that as the population grows there will be more electricity used and this will lead to more greenhouse gas emissions.

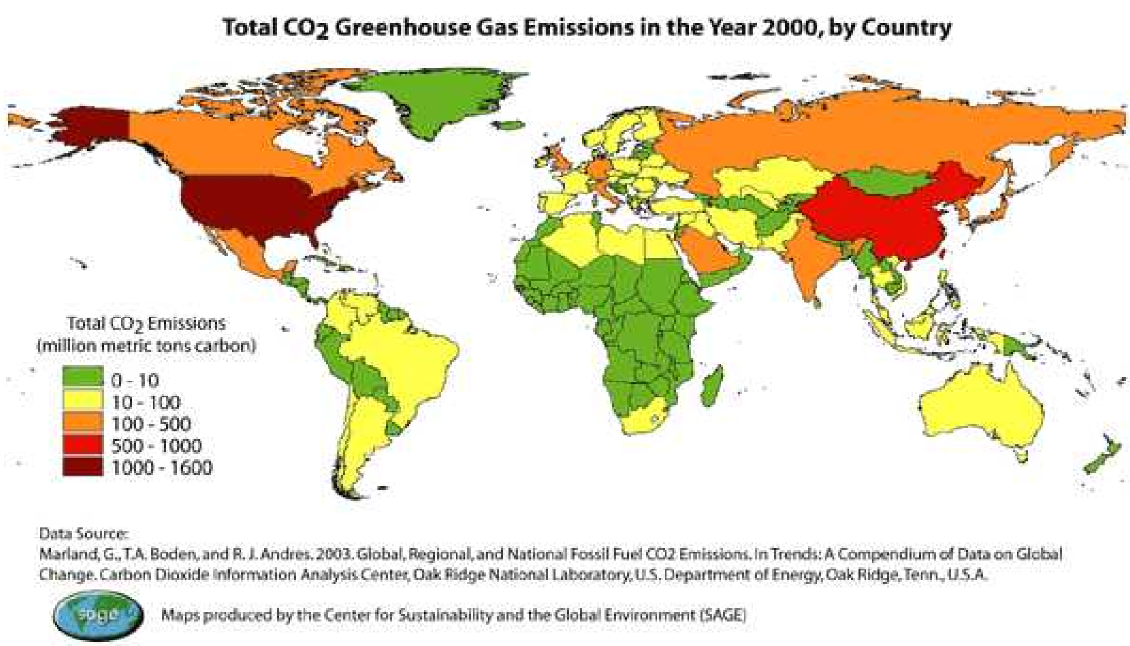


Figure 3: Global Greenhoues Gas Emissions by Country (Basu 2006)

From Figure 3 it is very clear to see that the United States is by far the leading greenhouse gas emissions producer in the world.

Special attention must also be paid to another factor influencing the amount of carbon in the atmosphere: trees. All plants have the ability to transform carbon dioxide in the atmosphere into oxygen through photosynthesis. With each year acres and acres of rainforest and other wooded areas are cut down for paper goods and other materials. Every recycled ton of paper saves approximately 17 trees and 462 gallons of oil (DEQ 2006). This is quite counteractive because as the world's population starts to produce more greenhouse gases, there are fewer plants to remove these gases. By cutting down trees and using them to produce paper goods we are creating more greenhouse gases because making paper produces many toxins such as sulfur, absorbable organic halides, chloroform, dioxin, and furan. This does indirectly affect Worcester Polytechnic Institute because we do utilize significant amounts of paper, however the data for this analysis would be too difficult to obtain so this source will not be focused on.

2.2.2 Greenhouse Gas Emissions in the United States

According to the Environmental Protection Agency's website (EPA.gov), each American emits roughly 1.9 Metric Tons of Carbon Equivalents per year. Figure 4 shows that in 1995 the United States produced the most overall tonnage of greenhouse gases, 6.6 MMTCE/million people, followed closely by Australia.

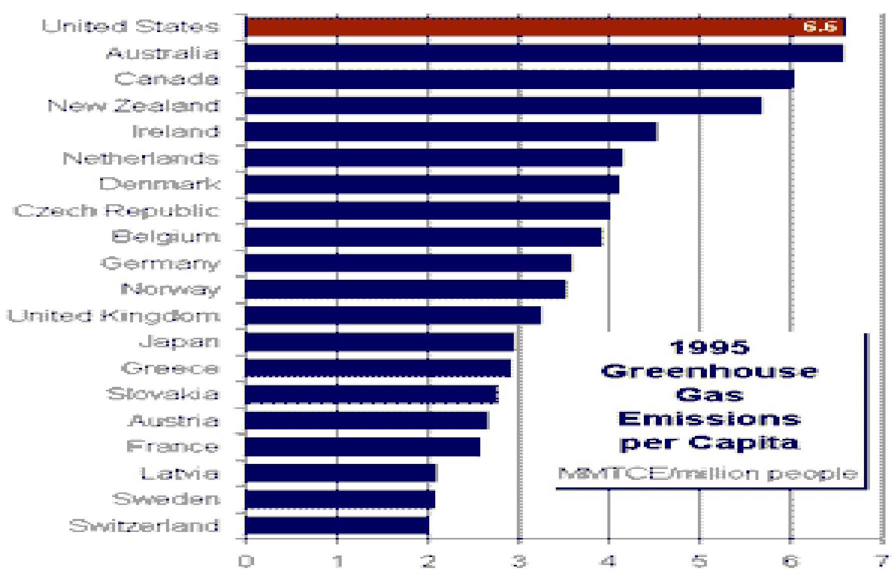


Figure 4: Greenhouse Gas Emissions per Capita (EPA Website)

Even today greenhouse gas emissions are increasing on a yearly basis in the United States. In 2003 the United States emitted 6.98 million metric tons of greenhouse gases, and 7.12 million metric tons in 2005, a 2% increase (Heilprin 2005).

For many years now, it has become very clear that there is an unequal use of energy from country to country. The population of the United States makes up 5% of the world's population however we consume 25% of the world's energy (U.S. Army 2005). This data makes sense when considering the number of vehicles the United States has; 243,023,485 in 2004 according to the Department of Transportation.

The fact that our country uses so much more energy than other countries is disturbing, but the fact is we are still focused on using fossil fuels such as oil and coal more than renewable sources is more disturbing. Using oil and gasoline has been a historic practice since the birth of country over 200 years ago. Trains and locomotives were steam powered but required coal to boil the water and the first cars were powered by diesel or gasoline. Using coal and gasoline were the smartest choices back then because they were fairly abundant and effective, but as time has progressed we have discovered better and cleaner alternative energy sources. Solar power and wind power see limited use in various homes and companies, nuclear power has become a source of electricity, hydrogen and ethanol may be applied sometime in the future as other sources of electricity; but why do we still rely on oil so much? No one can deny the power oil companies have on today's society and its decision makers. Most of this power and influence originates from the extremely high profits they generate; for example in the third quarter of 2005 Exxon-Mobile had a net-income of almost $10 Billion, its highest ever (Quinn 2005). Right now it seems like the best way for oil companies to turn a profit is to stay focused on gasoline and oil, but something needs to be done before these sources are completely depleted. Below is a pie chart depicting the breakdown of the United State's energy supply:

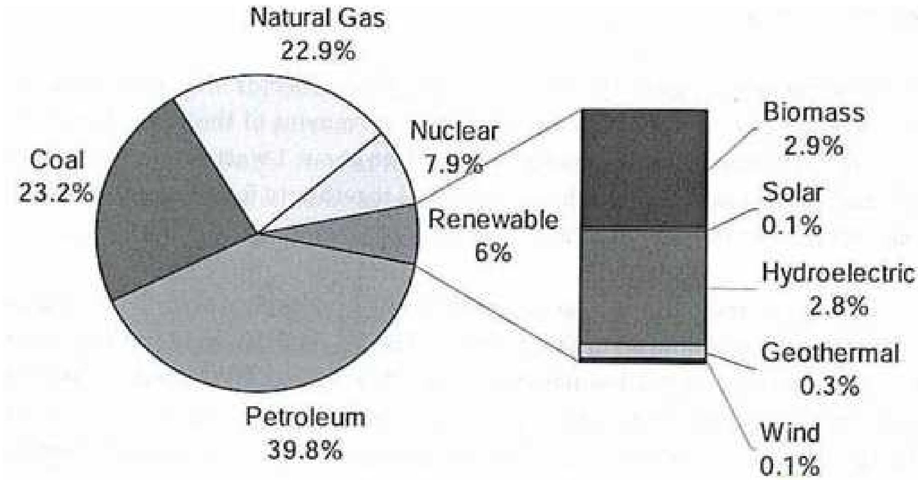


Figure 5: Roles of Renewables in the US Electricity Supply. (U.S. Army 2005)

2.2.3 Greenhouse Gas Emissions on a University Campus Level

A university campus may not seem like a legitimate source of greenhouse gas emissions but they are; Tufts University produced 15,000 MTCE in 1990 for 8000 students (Tuft Climate Initiative 2002). There are several benefits to a university for conducting a greenhouse gas emissions inventory and implementing alternative methods to help reduce these emissions. Most importantly it helps the environment by reducing harmful greenhouse emissions. Secondly, it gives the university a better image showing they care about the environment and want to help fix any problems they may be causing. Thirdly, an inventory gives the university a baseline value for future reference to see if there needs to be more done to reduce the gases or if they are making satisfactory progress.

The first step the Tuft's Inventory suggests is to define the parameters of the data that needs to be collected. Clean Air – Cool Planet breaks down the greenhouse gas emissions into different groups: energy, agriculture, waste and refrigeration (CA-CP eCalculator v4.0). WPI has no significant agriculture so this topic can be ignored for the time being. There are not a lot of sources of refrigeration on WPI but the chemicals in refrigeration have the highest Global Warming Potential (GWP) of 140-12,100 with carbon dioxide as the standard GWP of 1. The Tufts Inventory lists HFC-23, HFC-125, HFC-134a, HFC-152a, HFC-227ea as chemicals used in refrigeration. Their GWP's are significantly higher than carbon dioxide because they have the capacity to hold much more heat. Global Warming Potential is defined as the comparison of the gases' radiative forces and their respective atmospheric lifetime. It is used as a means to measure other greenhouse gases (GHG) against carbon dioxide.

2.3 The Fuels Leading to Greenhouse Gases

The sources of greenhouse gases are most often associated with the burning of fossil fuels such as coal, oil and natural gas. Unfortunately these compounds account for nearly all the energy we use in our daily lives, so it is a necessity to burn them. Until we find alternate sources to meet our energy needs, the combustion of those fossil fuels will remain a common practice.

2.3.1 Coal

Coal is a very important part of how the world gets its energy. When compared to the amount of oil, natural gas and other resources for energy, coal out weighs them all. The one draw back is that it is the dirtiest source of energy that we have. When coal is burned it emits sulfur dioxide (SO_2), nitrogen oxides (NO_X), particulates, and carbon dioxide (CO_2) (Westervelt 2005). The one advantage is that the supply of coal, saying that it is used at a constant consumption rate, will allow the United States to have a 260 year supply (U.S. Army 2005). Coal is mainly used to produce electrical power. According to the Energy Information Administration (EIA), in 2002 the distribution of energy produced in the United States by coal, nuclear, natural gas, hydro, and oil were 50%, 20%, 18%, 7%, and 5%, respectively. As we can see from these numbers coal is a very important part of producing energy.

There are four different types of coal that are mined. These types are lignite, sub-bituminous, bituminous, and anthracite. Lignite is a soft brownish-black coal that is the largest portion of the world's coal reserve. Sub-bituminous is a dull black coal that is more efficient and providing heat then lignite. Bituminous coal is referred to as soft coal because there is a lot of energy that is packed into this type of coal. Finally anthracite is a very hard coal that is very efficient when it is burned. It gives off a tremendous amount of heat which is very suitable when trying to heat a large area. Each of these different coals can be found in many different places such as Montana, Wyoming, Kentucky, Pennsylvania, and many others.

2.3.2 Oil

Petroleum or crude oil is a very important source of energy. Petroleum is a very efficient way to power certain transportation systems. The United States alone relies on oil based products for 97% of the energy for transportation systems (U.S. Army 2005). The world consumes more then 85 million barrels of oil per day. This is an enormous amount of energy whether it is expended through use of cars, trucks, or factories. Another huge part of oil consumption is heating the homes of millions. Over 7 million house holds are heated by heating oil. The largest sources of supply are Saudi Arabia, Russia, the United States, Iran, Mexico, China, and Europe's North Sea. Within the United States, the largest areas of production are the Gulf Coast – including the Gulf of Mexico, West Texas, California, and Alaska (Grant 2006).

The energy supply due to oil consumption in the United States represents about 39% (U.S. Army 2005). Oil is a major portion of our way to heat houses, keep factories running, and many other operations. Petroleum emits harmful gas just as coal and natural gases do. Petroleum produces carbon dioxide, carbon monoxide, nitrogen oxides, sulfur dioxide, and particulates. One of the many ways that oil pollutes the environment is when a spill occurs during drilling and the specific life forms in that certain location suffer. Petroleum has provided us with numerous ways to power certain machines and is a great source of energy that can be used effectively in many different aspects.

2.3.3 Natural Gas

Natural gas is a very unique source of energy because of how it is obtained. Natural gas is not easily located. Geologists and geophysicists have to survey the soil to decide whether or not there is a source of natural gas in a certain location. Once a possible source is found, a drilling team will then prepare to work. The natural gas that is pumped out of the ground is not that same as that which is used domestically. The pumped gas must first be purified because the raw gas has many pollutants such as oil and water (Natural Gas 2004).

Natural gas is a very desirable source of energy because it is fairly clean. Natural gas reserves are about 6,204 trillion cubic feet (Tcf) which is about a 66 year supply (Westervelt 2005). Methane is the main ingredient in natural gas. When natural gas is burned the products that are given off are carbon dioxide and water vapors. As we know carbon dioxide is a very harmful gas, but when coal and oil are burned there are much more harmful gases produced.

2.4 Why Greenhouse Gas Emissions is Such an Important Issue

The Greenhouse Effect is one the major problems facing our planet and has been since the Industrial Revolution. Many people believe that the Greenhouse Effect is leading towards Global Warming, which is a slow increase of the Earth's temperature. An increase in the Earth's temperature could lead to disastrous climate changes.

The most immediate effect would be more extreme weather patterns such as warmer summers and more devastating snow storms in the winter which is caused by the increase of moisture in the air. This extreme weather can lead to more heated-related deaths in the summer, more hypothermia-related deaths in the winter and it would also lead to more rainfall which causes flooding (Clean Energy 2005). Flooding is especially hazardous because it leads to contamination of water supplies and provides breeding grounds for insects to reproduce which then increases the likelihood on contracting insect-borne illnesses. If the temperature grew too much it could melt the polar ice caps which would cause permanent flooding on low-lying costal areas completely changing ecosystems in those areas.

The burning of fossil fuels releases harmful irritants into the atmosphere at an alarming rate. Before the Industrial Revolution, concentrations of atmospheric carbon dioxide were around 280 parts per million while today they are around 370 parts per million (Middlebury Inventory 2003). The addition of more harmful particulates in the atmosphere will lead to an increase in asthma and respiratory illnesses.

People should be aware that there are steps they can take on their own to reduce greenhouse gas emissions. The ICLEI documents are a very good source of information regarding cities worldwide that have taken active steps to reduce greenhouse gas emissions. Some of these steps include switching to LED lights which use less energy, turning off all lights at night, adding reflective material to roofs to reflect heat which can keep the house cooler in the summer, purchasing energy efficient appliances and using public transportation whenever possible (ICLEI 2003). These may seem like small steps but when everyone starts doing them, the results become significant very quickly.

2.5 Analyzing Studies from Other Universities

Many reputable universities have already conducted their own greenhouse gas inventories and have published papers on their methods. Some of these universities included, but are not limited to, Tufts University, Tulane, Harvard, Penn State and Middlebury. There has been several greenhouse gas inventories conducted on the city of Worcester by students at Clark University. Clean Air – Cool Planet is another very important tool we will be using which provides us not only a protocol to follow for conducting a university inventory but also a spreadsheet calculator to make calculating carbon emissions much easier.

Looking at these methods can provide us invaluable advice on how to go about conducting our inventories. For example the Tuft's inventory advises us to be cautious when looking at fuel data used by the university. They say in order to get more accurate results we should take our data from the amount of fuel consumed and not the amount of fuel bought because schools like to stockpile fuel certain years which would lead to much higher emissions one year and drastically lower emissions the following year. It is also encouraged that in order to complete a thorough greenhouse gas emissions inventory non-carbon gases must also be taken into account. These gases included methane, nitrous oxides and sulfur hexafluoride. Methane mostly arises from solid waste, which we will try to evaluate as best we can, and domesticated animals which WPI does not have. Chemicals used in refrigeration will be taken into account and in accordance with EPA regulations. By law they are required to keep accurate records of amounts used but as we found data were incomplete and difficult to obtain.

One of the most useful university inventories we looked at came from Connecticut College. What we particularly liked about this inventory was the way in which the authors presented their data. They presented the total emissions data for the entire school which included all sectors and direct sources. What they did next was plot the energy used per student by year and the emissions per student by year. We felt this gave an accurate way of showing whether emissions were increasing as a result of just an increase in population or resulting from reckless use of fuels. They presented these values with those from other schools to show how Connecticut College compared to others. What they did next was look at the individual sectors and sources and analyzed each individual one.

We will also look at an emissions report done on the whole city of Worcester by Carissa Williams, a Clark Professor. From this report we are presented with a very in-depth paper which we can use as a template to model our own paper after. This paper also utilized the technique of presenting an overall emissions report first and then proceeded to break it down by sector immediately afterwards. They used software based calculations like we plan to use but they also plan on doing their own calculations which is nearly inevitable. However some of their calculations, miles traveled in vehicle for example, are very complicated and to get the most accurate estimates they used algorithms. Most likely we will not obtain enough data to make the same calculations but instead for uncertain areas, like transportation, we will make and list all the assumptions to fill the holes in the data.

2.6 Summary

The problem of greenhouse gas emissions is a very significant and very global problem that needs to be dealt with sooner than later. A greenhouse gas emissions inventory is a valuable tool to gauge how environmentally clean your city or university is because a lot of care needs to be taken while performing one. We will work through these problems to conduct a greenhouse gas emissions inventory on energy uses at WPI.

Chapter 3: Methodology

The primary goal of our project was to determine the amounts of greenhouse gases directly and indirectly produced as a result of campus activities at WPI. We implemented a system aimed at tracking greenhouse gas emissions yearly. Most of the project was based on data collection and analysis which our group then handed over to the Policy group which they in turn took and used to begin forming a policy for WPI to implement on greenhouse gases.

We worked on this project A through C terms on campus, spanning from August 24, 2006 to March 1, 2007. We did most of our data collection from October 24, 2006 until December 14, 2006 and we then spent the remainder of our time on the project analyzing all our collected data and working with the policy team to make sense of it and work on a way to present it to the decision-makers at WPI.

The basic outline for how we achieved our goals is listed below:

- Choose the best approach to complete our inventory and analysis of greenhouse gas emissions.
- Gathered various types of data on energy use at WPI by meeting with different departments on campus.
- Input the data in the Clean Air – Cool Planet calculator and also created many graphs on our own using excel spreadsheets.
- Evaluated the data and discussed how WPI is doing with its current and past emission rates.
- Cooperated with the Policy group to aid them in advising WPI administration to implement new policies to regulate and ultimately reduce greenhouse gas emissions on campus.

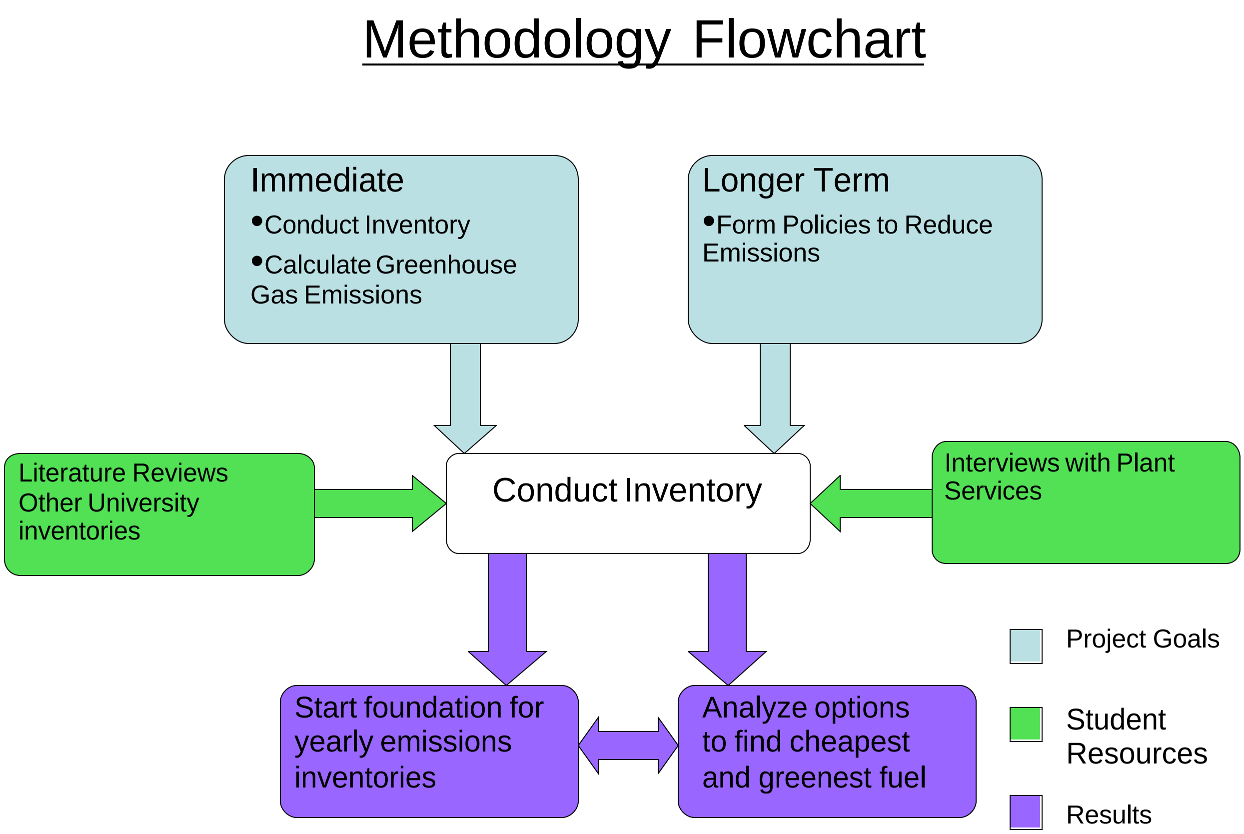


Figure 6: Methodology Flowchart

3.1 Choosing the Best Approach to Complete Inventory

We needed to figure out the best approach for completing our inventory and analysis at Worcester Polytechnic Institute. After looking at the methods that other schools had taken, we compared the benefits and downfalls of each school's approach. We assessed things such as how in depth each was, problems that arose during their inventory process, ease of use (if we were able to find all information needed to complete that type of inventory), and useful information that can be extracted from each approach. We looked at the Clean Air – Cool Planet calculator, different methods that other colleges used for their analysis, and also doing our own inventory and analysis.

3.1.1 Greenhouse Gas Emissions Inventory Calculator

By analyzing each approach we decided that a mixture of all of them would be the best for us. An approach taken by many schools, especially in the northeast, is one that is laid out by the organization Clean Air – Cool Planet's website cleanair-coolplanet.org. The site has a campus climate action toolkit. Included in it is a step by step guide to doing a GHG inventory on a college campus, a GHG Emissions Inventory Calculator and a campus action plan when the inventory process is completed. The GHG Emissions Inventory Calculator is an MS-Excel-based spreadsheet which required data about the school's energy and fuel usages. We also used many similar graphs and tables that were found in other schools reports, but modified them to fit to our specific data.

The inventory calculator can be a very in depth tool or can be done very quickly with minimal data. The in-depth approach requires much more data, but will give a better estimate of the school's actual emissions. Because very accurate records were not kept at WPI in years past, we attempted to do the in-depth approach by using all information that we had, but we could only do so much with it.

The Clean Air – Cool Planet Inventory Calculator gave us a good place to start for the first inventory at WPI. Since we had better data going back in different categories we needed to come up with some analysis tools of our own. We attempted to take that calculator and make a more permanent system at WPI which members of plant services, the heating plant, accounting and the registrar's office could input or have work study students help them with. The goal here is that with constant data inputs throughout the year, WPI would have accurate records of greenhouse gases that are updated yearly so they could observe what progress they are making in reducing them.

3.2 Gathering the Necessary Data

The most crucial part of our project was to collect any available data that we could. Without this data we could not complete a very accurate analysis. We received most of our data from the Plant Services Department, the Admissions Office, the WPI Power Plant and the Accounting Office. These were the most valuable sources, but we also found information from other sources and research of our own. Before we started we first needed to decide which information we would include or exclude from our campus greenhouse gas emission inventory. There are many different things that lead to greenhouse gas emissions such as agriculture and concrete. WPI does not use much agriculture so this would not be a significant source that would effect the overall emissions on campus. Also off-campus apartments and other student housing would release gases, but the data would be far too difficult to obtain. Instead we focused on energy related emissions including oil and natural gas burned on campus, the emissions from the electric company that provides us with electricity, solid waste, refrigeration, commuting students, faculty and staff, and students traveling away for IQP and MQP project work. We chose these sources because this was the best data that we were able to obtain.

The bulk of the information required to successfully complete our project was gathered from the members of the Plant Services Department, especially Mr. John Miller. After numerous meetings, he provided us with as much electricity data that he could come up with. He also had some data on the amounts of natural gas and oil used as well as basic cost data. He was also able to provide us with electricity data dating back several years and a brief explanation of how the electric system is set up at WPI. WPI has an electricity meter for the main campus which measures the buildings located within Park Ave, Institute Rd, Boynton St and Salisbury St. There are also individual meters for the rest of the buildings on campus including buildings such as the Stoddard and Institute resident halls. Mr. Miller had good information on the WPI main campus electricity meter going back to 1996, but only had good data on the entire campus for one year. The main campus meter allowed us to see how WPI has been progressing over the past 10 years with respect to electricity because it accounts for roughly 90% of the total electricity consumed at WPI. He also had some information regarding the suppliers of electricity to WPI and advice on how to contact them to ask their percentages of fuels used for generation of electricity. Mr. John Miller also got us the square footage of each building and we just had to add each of them up to get a total square footage for each year.

The Admissions Office provided information on how many students attend WPI each year. The information we gathered was somewhat scattered and we had to put it all together. We got the information of the number of students, commuter students, faculty and staff. The problem with the commuter students and faculty and staff was the fact that it did not tell us how far each traveled. The only information we were provided with was whether each lived in Worcester or Worcester County, but we had to make some assumptions as to how far the average commuter traveled. Another problem that we had was that the older information had included fraternities as commuter students up until the recent years. Because of this the number of commuters had looked much different until we got a chance to fix them.

Lastly we did some research on our own. Once we found out where we get our electricity from, we needed to find out what type of electricity it is, whether it's renewable or from burning coal or oil. We had to directly contact the companies that we purchase electricity from and find their custom fuel mixes. Other information that we had to find on our own was information such as what happens to the trash that we produce, is it burned in a mass incinerator or does it just sit in a landfill? Information like this effects our emissions greatly and was very important to find out.

We dedicated a lot of time towards gathering the necessary data. This was the most important aspect of our project and probably the most difficult. All of the data was not in one place so we had to work hard to gather it all. With all of the information that we received, we kept good records of whom we got it from and when we got it. It is necessary to show that our information is credible and accurate.

Here in

Table 1 is a list of data sources and recommendations that we have and also some assumptions that were made in each data category:

Table 1: Data and Source Table

Data/Source	Recommendations	Assumptions
Electricity, John Miller	Although John Miller is retiring it would be helpful to aid his successor in implementing a newer system of data collection. It would be beneficial to have complete electrical records organized in a computer system that is easy to access and implement.	There is no electricity data for all the meters on campus prior to 2005 so we used only the data for the main meter going back to 1996.
Oil and Steam, Bill Grudzinski	Mr. Grudzinski has a model system in mind that he is working towards achieving which is the same as outlined above. He needs only to dig up the lost steam data for 3 years as well as organizing the oil data a little better.	For the steam data that is lost we took the worst case scenario and used the largest data point
Refrigerants, Dave Lindberg	The data for the refrigerants and other chemicals which emit GHG's is very poor. Detailed logs should be kept as to when these chemicals get delivered as well as when they are used and how many are being kept in storage. Ideally this information would be updated on how much was used not on how much was stored or bought.	None of the chemicals we use at WPI are listed in the CA-CP calculator so we had to list them in the "Other" column so there are no coefficients for calculations.
Students, WPI Factbook	We found the WPI fact book to be very helpful. It would be very helpful if WPI published these fact books every year.	We had to do some calculations to find the data for years other than 2004 & 2006 so it's very difficult to get precise data on how many students were attending at a given time.
Facult/Staff, Cynthia Pelligrino	Maybe WPI could do a survey of a poll every year where their employees fill out how many miles they drive each year as well as if they carpool or take public transportation.	Like with the student data we had to assume how many miles they traveled each day and how many trips they made per year.
IQP, MQP travel data Natalie A. Mello	The data for this portion was kept very well with great detail about how many students when to each site in what year and in what term.	We assumed that all travel initiated from Worcester and all flights were direct.

3.2.1 Methods on Collecting Electricity Data

We got directly in contact with the electric companies because it was necessary to find the percentages and fuel mixes used by these companies to generate the electricity. At National Grid we communicated with an employee named Kelly who forwarded us to a website which had the most recent breakdown of fuels used to generate electricity for WPI from April 1, 2005 until March 31, 2006. WPI has been purchasing electricity from National Grid and its predecessor Mass Electric since the school began buying electricity. We have electricity data going back to 1996 but requests to find out how long the fuel mixes for National Grid going back several years yielded no success. During our conversations with John Miller he told us that within the next few months WPI will purchase its electricity from Direct Energy. After looking online we were able to find a fuel mix for Direct Energy that was used from October 1, 2006 to December 31, 2006. After speaking to our advisor we found out that Select Energy is another local supplier of electricity in the area so we tried to look for their fuel data so we could have a set to compare to but we soon realized that Select Energy was bought out by Hess. We spoke with a Hess employee Andrew Short through email who provided us with the electricity mix for Hess for 2005. We made requests to these individuals to forward any fuel mix data going back several years but we were unable to obtain any.

One thing in particular that we noticed when inputting this data into the calculator's custom fuel mix spreadsheet is that the companies do not specify which number oil they use, for example #6 or #2. We wanted to see if there was a big difference in the emissions from inputting #5 and #6 oil or #1-4 oil.

Table 2: Difference between #6 and #2 Oils

Fuels	Metric Tons C per 1,000 Gallons
#6	2.9
#2	2.8

Comparing the two carbon equivalences shows that there is not much of a difference. The calculated difference between using #2 oil and #6 oil is 4.8%. Since there is not much of a difference and #6 oil is not being used very often for this use anymore, we decided to assume oil use was #2 oil.

3.2.2 Methods for Calculating Transportation Data

Obtaining credible values to input into the calculator for the transportation sector was difficult. For example it would be extremely hard and time consuming to figure out the percentage of faculty, staff and students that carpool or ride with another colleague to campus. In this instance we will assume that 100% of faculty, staff and students drive to WPI alone. We will do this because it makes the most sense and it also gives us the worst case scenario of how bad the greenhouse gas situation at WPI really is. Another valuable piece of data that we are unlikely to obtain is how many days a year staff and faculty travel to WPI. We looked up that there are 120 days of class for undergraduate classes. We have no way of figuring out how many days during the year faculty make the trip to WPI because some do not come everyday and some continue to come during the summer. We took a rough estimate to be 150 days during the year that the average faculty member travels to campus. We also will need to know the number of miles the faculty members travel per trip. The data we were sent by Cynthia Pellegrino, the Assistant Director of Human Resources at WPI, gave a number of faculty and staff members that lived in the city of Worcester and another number that lived in Worcester County. We went to a map and found that the farthest city from Worcester still in Worcester country is 30 miles away so for a rough estimate we assumed that the average faculty member travels half that distance, or 15 miles per trip. We assumed that WPI community members living in Worcester commuted 0 miles to come to WPI.

The same was true for staff members because we are not sure how many days in a year the average staff member traveled to campus but we were pretty sure that it would be more than faculty members because most of the campus remains open year round and people need to be here to keep it running. We assumed that the average faculty member makes trips to WPI 220 days a year and that they also traveled 15 miles 1 way to get to WPI.

Ideally for this category we would have the address of each faculty and staff member so we could calculate exactly how many miles each person travels a day. We feel that this could easily be facilitated next year by taking a survey of the faculty and staff members at some point during the year by including the survey with their pay check or something similar and having them return the form. Only a zip code would be needed to get more accurate data. This data could then be input into the same data system as the one currently used from which we were given data.

3.3 Implementation of the Calculator

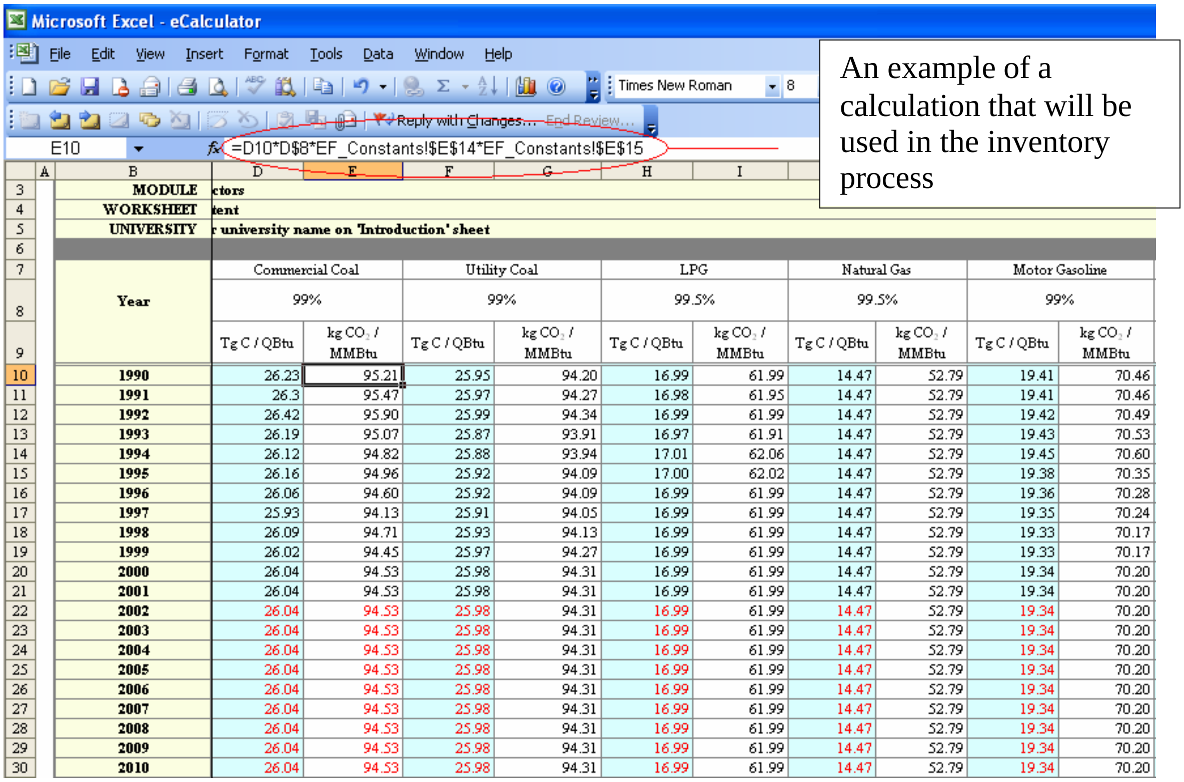
The first step to completing this calculator was to get the general information about the school. It asks for the energy budget of the school and if there is any other money set aside for research. Categories like this were not attainable so we with left them blank or put zeros in the corresponding rows. Next it asks for the population of the campus, full time, part time, and summer school students, faculty and staff. It then takes into account the physical size of the campus, particularly the square footage of all the buildings on campus. This information was used to analyze the carbon emissions per student and per square footage at the school. With this information we were able to compare our campus to others of similar size and population.

The second step to completing the calculator was to look at the on and off campus sources of energy. It requires the total amount of electricity and fuels needed to steam/chill water purchased by the school as seen in Figure 7. There is a section that you can either chose which electric region you are in, or enter your own custom fuel mix. Each electric region gets their electricity from different sources, resulting in a unique amount of greenhouse gases produced for each. The regions are broken up according to the average that is used in that region. We wanted to do a more in depth analysis of this so we opted to enter custom fuel mixes. The data collected for oil, fuel and coal burned on campus was then input into the calculator for further analysis. There was another section of the calculator that asked for the steam and electricity output of the plant. The plant on WPI's campus is solely for producing steam. We entered the amount of steam output and also the efficiency of the system.

Purchased Electricity									
Electric produced off-campus	On-Campus Cogeneration Plant								
All users: Click to select your electric region or "custom" if you know your electric fuel mix	Residual Oil (#5 - #6)	Distillate Oil (#1 - #4)	Natural Gas	Propane	Coal	Electric Output	Steam Output	Electric efficiency	Steam Efficiency
Nationwide									
kWh	Gallons	Gallons	MMBtu	Gallons	Tons	kWh	MMBtu	%	%
	587,747	0	0	0	0	0	74,139,000	0%	81%
	520,551	0	0	0	0	0	62,821,000	0%	81%
	566,681	0	0	0	0	0	72,672,000	0%	81%
	624,879	0	0	0	0	0	76,989,000	0%	81%
	671,240	0	0	0	0	0	79,022,000	0%	81%
	598,315	0	0	0	0	0	75,137,000	0%	81%
16,662,380	615,384	0	0	0	0	0	75,807,000	0%	81%
15,742,320	610,991	0	0	0	0	0	77,527,000	0%	81%
16,178,640	585,719	0	0	0	0	0	74,443,000	0%	81%
16,950,240	590,446	0	0	0	0	0	72,487,000	0%	81%
17,097,840	628,137	0	0	0	0	0	69,545,000	0%	81%
18,638,880	628,137	0	0	0	0	0	81,599,000	0%	81%
18,681,600	628,137	0	0	0	0	0	71,074,000	0%	81%
17,033,280	702,500	0	0	0	0	0	62,083,000	0%	81%
18,513,360	628,800	0	0	0	0	0	81,599,000	0%	81%
17,987,760	192,050	98,890	40,245	0	0	0	81,599,000	0%	86%
18,795,200	0	328,902	38,962	0	0	0	81,599,000	0%	86%

Figure 7: CA-CP screenshot of purchased electricity and the on-campus plant

At the same time we were inputting our data we were learning more about the calculator every day. There was information that had already existed in the calculator. These numbers were used for calculating emissions and also coming up with some of the different tables and graphs. An example of some numbers that had already existed in the calculator was emission factors for coal, natural gas and oil. The emission factors change every year as seen in Figure 8. Numbers such as these were helpful to us later in the project when we were coming up with equations, tables and graphs of our own.



Year	Commercial Coal		Utility Coal		LPG		Natural Gas		Motor Gasoline	
	99%		99%		99.5%		99.5%		99%	
	Tg C / QBtu	kg CO_2 / MMBtu	Tg C / QBtu	kg CO_2 / MMBtu	Tg C / QBtu	kg CO_2 / MMBtu	Tg C / QBtu	kg CO_2 / MMBtu	Tg C / QBtu	kg CO_2 / MMBtu
1990	26.23	95.21	25.95	94.20	16.99	61.99	14.47	52.79	19.41	70.46
1991	26.3	95.47	25.97	94.27	16.98	61.95	14.47	52.79	19.41	70.46
1992	26.42	95.90	25.99	94.34	16.99	61.99	14.47	52.79	19.42	70.49
1993	26.19	95.07	25.87	93.91	16.97	61.91	14.47	52.79	19.43	70.53
1994	26.12	94.82	25.88	93.94	17.01	62.06	14.47	52.79	19.45	70.60
1995	26.16	94.96	25.92	94.09	17.00	62.02	14.47	52.79	19.38	70.35
1996	26.06	94.60	25.92	94.09	16.99	61.99	14.47	52.79	19.36	70.28
1997	25.93	94.13	25.91	94.05	16.99	61.99	14.47	52.79	19.35	70.24
1998	26.09	94.71	25.93	94.13	16.99	61.99	14.47	52.79	19.33	70.17
1999	26.02	94.45	25.97	94.27	16.99	61.99	14.47	52.79	19.33	70.17
2000	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2001	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2002	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2003	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2004	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2005	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2006	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2007	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2008	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2009	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20
2010	26.04	94.53	25.98	94.31	16.99	61.99	14.47	52.79	19.34	70.20

Figure 8: Screenshot of CA-CP calculator emission factors

3.3.1 Other Issues that Contribute to Greenhouse Gas Emissions

Greenhouse Gas Emissions and the calculator take into account not only how much fuel we burn but also what kinds of fuels we burn. Emissions are greatly effected whether we are burning #2 oil or coal. The calculator allowed us to explore in depth how efficient WPI is at using energy. The final inputs to the calculator were the categories such as solid waste produced by the campus and the amounts of refrigerants used. We thought that this information would be readily available, but the only information Mr. John Miller could come up with was the average amount of waste produced each year.

Another thing that we thought would not be difficult to obtain was the data on GHG-related refrigerants and other chemicals. All campuses in the US are required by the EPA to keep track of all refrigerants and other chemicals on campus. Chlorofluorocarbons (CFCs) are being phased out because of the extreme damage to the ozone layer, but other fluorocarbons which are just as harmful are used as refrigerants. The only information that was kept on these was the amounts purchased, not the actual amounts that were used each year.

The last few categories were much vaguer than the others, and we tried to obtain any information that we could. The first thing it asks for is any other fuels, oils, coal, propane, or incinerated waste burned. These are possibly used for heating, cooling, cooking, labs, ect. Because we felt that theses categories would be very difficult to obtain and would have a minimal effect on the overall emissions we decided to exclude these topics.

Another part of the inventory that we decided to leave off was the inventory for some of the transportation category. This included the university fleet (vehicles used by campus police or plant services) and air travel by teachers for business trips. After speaking with John Miller, there is no separate fuel data kept for the university fleet. The fuels that they use are added in with the overall fuel burned on campus. In our research of looking at other schools, we had seen that things like this were also insignificant to the overall picture of greenhouse gas emissions at their school. We did however account for commuter students, faculty and staff and also the air miles traveled by students on IQP and MQP study abroad programs.

Commuter Traffic

Worcester Polytechnic Institute

Students	Student fuel efficiency	Percent Commuting by personal vehicle	% TOTAL STUDENTS (Column C) Driving alone	% TOTAL STUDENTS (Column C) Carpooling	Trips / Day	Days / Year	Miles / Trip	Total Distance	Fuel Consumption
#	mpg	%	%	%				Miles	Gallons
-	20.42							-	-
-	20.56							-	-
-	20.63							-	-
-	20.42							-	-
-	20.84							-	-
-	21.06							-	-
3,380	20.91	100%	100%	0%	1.00	140	15	7,096,950	339,409
3,361	21.19	100%	100%	0%	1.00	140	15	7,057,050	333,090
3,391	22.10	100%	100%	0%	1.00	140	15	7,120,050	322,174
3,504	22.10	100%	100%	0%	1.00	140	15	7,357,350	332,912
3,530	22.10	100%	100%	0%	1.00	140	15	7,413,000	335,430
-	22.10							-	-
-	22.10							-	-
-	22.10							-	-

Figure 9: Screenshot from CA-CP on Student Transportation

3.4 Greenhouse Gas Emissions Inventory Analysis

Initially the calculator came up with many different sheets of data with conversions, global warming potentials of specific gases, emission factors, and carbon contents of coals, oils and gases. These were useful as we could refer to them in the implementation of our own analysis tools. An understanding of these things was very important with this project.

Once the GHG Inventory Calculator was completed there were many tables and graphs that were automatically produced. There were graphs of how the emissions of the school have changed over the past five years, the amount produced per square footage of buildings, amount per community member (including students, faculty and staff), and the total amount of energy used and GHG emissions.

Along with the graphs many tables were produced. There were tables that breakdown what is in the graphs, the numbers behind them. They stated the overall amount of carbon and other GHGs produced by WPI's campus. Percentages of where exactly the gases came from were also available. Appropriate analysis and discussion of these graphs and tables can be found in the results and analysis section. Even with all of the graphs and tables that were produced it was not sufficient enough to provide a complete clear story of the emissions at WPI so we were required to implement some of our own graphs and tables.

3.4.1 Using our own spreadsheets to calculate emissions

We wanted to go further in depth and figure out the contributions from each fuel on the total emissions. We made our own spreadsheet which took the total electricity usage for the main meter at WPI going back to 1996, obtained from John Miller, and figured how man kWh were produced by each fuel. On the Center for Transportation Analysis website we were able to obtain conversion factors for Million Metric Tons Carbon per QBtu.

Table 3: Carbon Conversions

Fuel	MMTC/Qbtu
Residual	21.49
Natural Gas	14.47
Coal	25.98

From these values we can convert to MMTC per kilowatt hour because we know that there are 3,412 Btu in a kWh.

Table 4: MMT of Carbon per kWh

Fuel	$(MMTC/kWh)x10^{-11}$
Coal	8.87
Natural Gas	4.94
Residual	7.34

Using these values we could multiply the total number of kWh generated by one of the three fuels by the corresponding value in Table 4 and obtain the MMTC per each fuel.

Table 5: Section of Spreadsheet showing contribution of individual fuel to overall emissions

National Grid Data				
Year	kWh Used	% Coal	kWh from fuel	MMT from Coal $(x10^{-4})$
1996	16662380	0.12	1999485.6	1.77
1997	15742320	0.12	1889078.4	1.68
1998	16178640	0.12	1941436.8	1.72
1999	16950240	0.12	2034028.8	1.80
2000	17097840	0.12	2051740.8	1.82
2001	18638880	0.12	2236665.6	1.98
2002	18681600	0.12	2241792	1.99
2003	17033280	0.12	2043993.6	1.81
2004	18513360	0.12	2221603.2	1.97
2005	17987760	0.12	2158531.2	1.91
2006	18795200	0.12	2255424	2.00

After this was complete we added the three emission totals together to get an overall emissions result for each year. We did not include the other fuels as sources of Carbon emissions because they do not emit any.

From John Miller we managed to get our hands on a year’s worth of electricity bills as well as energy budgets which gave us pricing for National Grid electricity and Direct Energy for 2006. We called and spoke to an employee at Hess Corporate named Mr. Tang who gave us a price over the phone. However the price for Hess was roughly 3 cents per kilowatt hour less (9.4

cents/kWh) than the other two companies so we believe this quoted price was just a rough estimate that does not take into account any delivery fees that are included in the National Grid and Direct Energy prices. With these prices and emissions data we can calculate how many total emissions we could figure out which electricity companies are greener, we could figure out the number of emissions we would be saving by using a greener electricity company and could calculate the extra cost of reducing these emissions.

Other calculations, graphs and tables like these were produced for the analysis of oil and other fuels used on campus. We did things such as normalizing the fuel burned per degree day to eliminate large spikes in the graphs during colder months. We also normalized these graphs by the square footage of the campus. As the campus grows larger we can expect to be burning more fuels to keep the campus warm. Graphs like these are very helpful to us for explaining to other people how WPI is doing with its energy usage and GHG emissions.

3.5 Cooperation with the Policy Group to Form New WPI Policies

Our project is the foundation for a much bigger project which aims at getting WPI to address the problems associated with greenhouse gases and form policies which would limit the amounts of these gases produced. Once we collected our data and determined how WPI's emissions have been over the last five years, we worked with the Policy group to come up with strategies on how to reduce them. It is now our challenge to present these strategies to the decision makers of WPI with our data backing them up to try and reduce WPI's overall greenhouse gas emissions.

This is probably the most important part of the project because we need to have the data make sense for whoever we are presenting to. Also a lot of the information we will include in our report is technical so it is imperative that we make the data as easy to understand as possible, assuming that the people we will present to have no prior knowledge of greenhouse gases. Another aspect we have to be careful about is convincing WPI to take action because it will most likely cost them money to implement the plans that we have come up for them. Most of the specific costs and numbers will be left to the policy group, but it is more expensive to use greener sources of energy: solar energy is especially expensive because a new grid system would have to be built to transport the energy from the panels. A new more extensive recycling program, switching to alternative fuel sources, purchasing electricity from companies using more environment-friendly plants and making buildings more energy efficient are all ways to reduce greenhouse gases, but they cost money. We need to get the point across that spending more money now could result in saving money several months or years down the road, but more importantly a cleaner environment.

Another aspect of our project with the policy group was to discuss and advocate for yearly collections of emissions data. Of course this would be a tremendous effort on the part of Plant Services and other departments, but we believe it is a crucial part to this project because it allows WPI to monitor emissions every year and see if the steps they took to reduce the emissions are really working. We have talked with John Miller and Bill Grudzinski to figure out the easiest possible ways that they would be able to implement this. They both agreed an online database would be best and also easy for others trying to view this information.

3.6 Conclusion

The goal of our project was to successfully account for how many greenhouse gases WPI emits through energy use and gauge whether or not WPI is increasing or reducing the amounts of these gases based on previous years' amounts. We ran into some problems in our data collection and analysis, but managed to get past them and complete our analysis. We will give recommendations to other groups trying to complete a similar type of analysis in the future in our future recommendations section. This methodology that we have put forth allowed us to complete the inventory and provided a foundation for yearly inventory collections. Our results and analysis also act as evidence that drafting new policies at WPI to reduce these harmful emissions is a must.

Chapter 4: Analysis and Results

From 2002 to 2006 the direct emissions from WPI have decreased from a total of 20 Million kg CO_2 to 18 Million kg CO_2. However from 2005 to 2006 they have increased by roughly 2%. This chapter is dedicated to stating the overall emissions we calculated for fuels used to heat the campus, electricity use and transportation. For the heating and electricity sections we analyze how much we could reduce emissions by using the greenest fuel and also the cost of doing this.

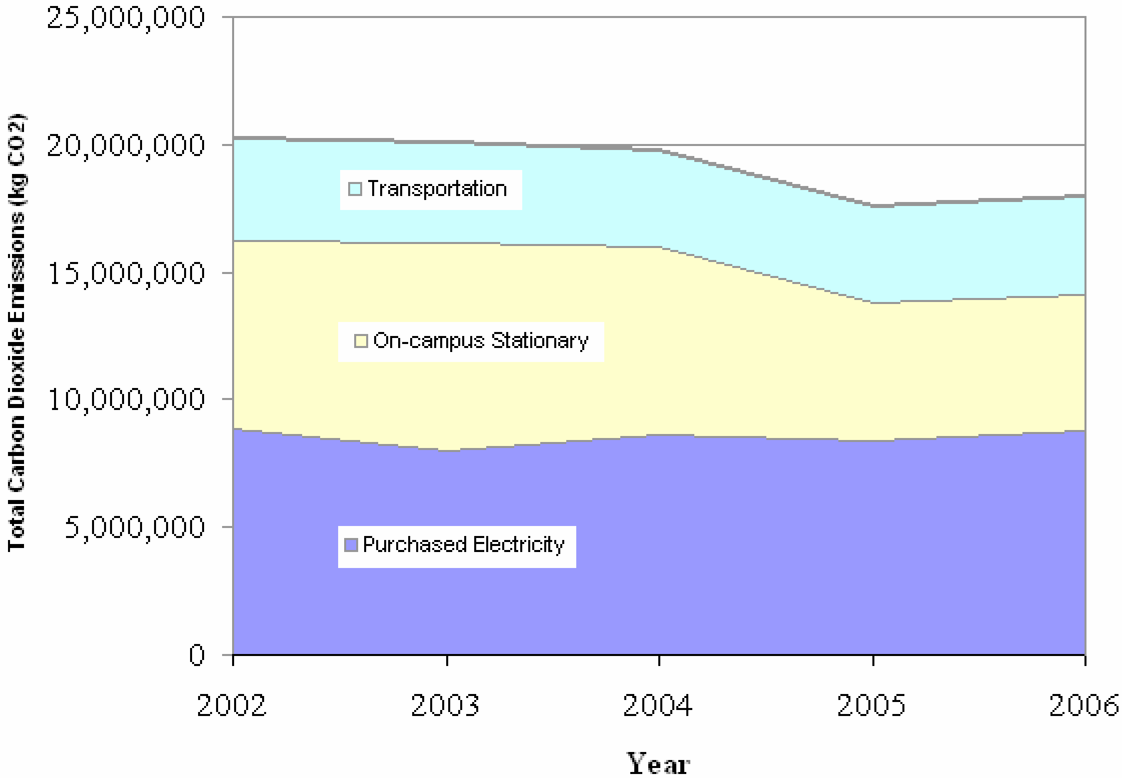


Figure 10: Emissions broken down by sector at WPI 2002-2006

Several things are immediately apparent from a brief view at this graph. First we can see that Purchased Electricity and On-campus Stationary (heating fuels) make up most of the emissions WPI generates. The second most obvious thing is that the emissions were reduced from 2004 to 2005 by about 3,000 metric tons. From our inventory and data collection we can say with confidence that this arises by the new boilers WPI installed in 2005. The new boilers are more efficient (86% compared to 81% in the old ones) and use a combination of #2 oil and natural gas. The old boilers used #6 oil which emits more carbon dioxide per gallon.

The population of undergraduate students at WPI has increased from 3,170 to 3,313 from 2002 to 2006 a 4% increase. We wanted to look and see if the increases and decreases and emissions related to how many students were enrolled at WPI. First we looked to see if overall on-campus energy use from oil, natural gas and electricity varied much per student.

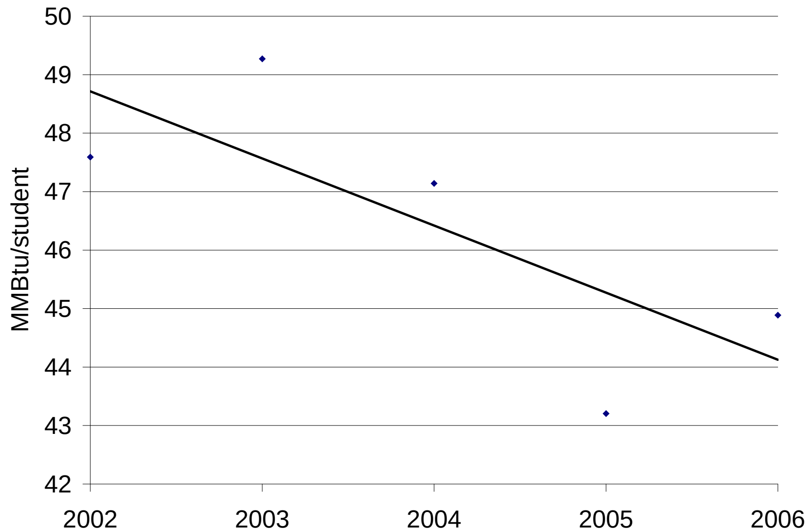


Figure 11: Overall Energy use per Student

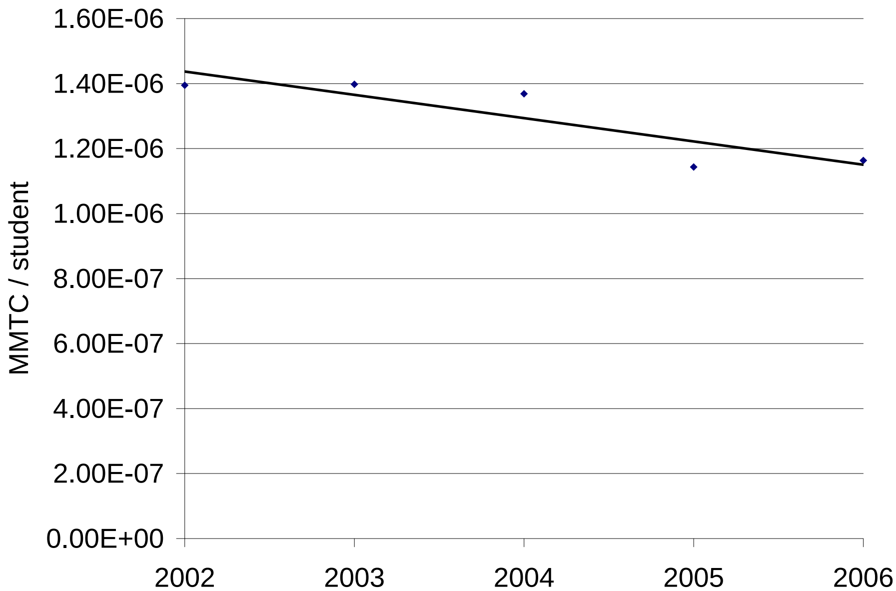


Figure 12: Overall Emissions per Student

We see that over the years 2002 to 2006 the Million Metric Tons of Carbon per student has decreased from 1.39×10^{-6} MMTC to 1.16×10^{-6} MMTC a 17% decrease.

4.1 Overall Emissions for Oil Consumption

Figure 13 shows the overall emissions for the consumption of oil and natural gas used on campus. Figure 13 takes into account the amount of #6 and #2 oil as well as natural gas for the years 2002 to 2006. In 2005 the plant switched from #6 oil to a combination of #2 oil and natural gas.

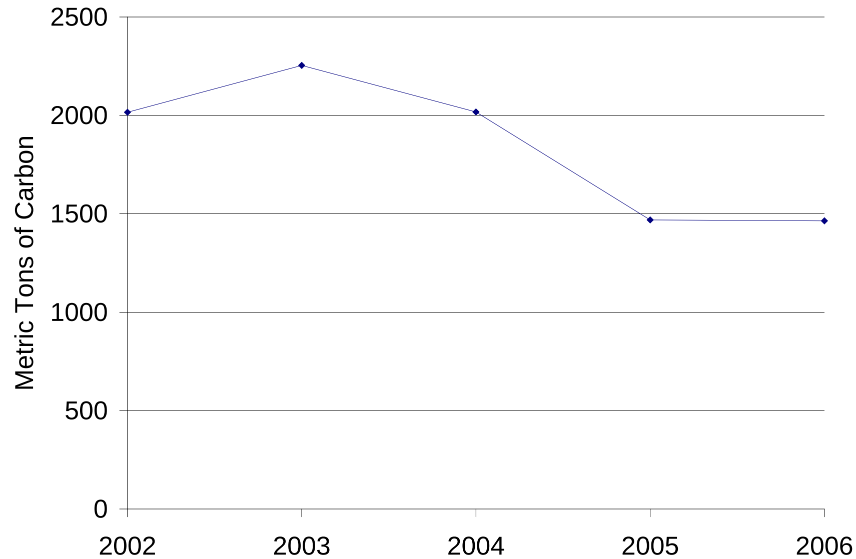


Figure 13: Overall Emissions as a result of Oil and Natural Gas Consumption

In the year 2003 the amount of emissions produced by #6 oil peaked at around 2300 Metric Tons of Carbon. As time progressed the amount of emissions began to fall because in 2005 WPI changed the boiler system to more efficient boilers. WPI also switched from #6 oil to a combination of #2 oil and natural gas. There was a 27% drop in emission between the years 2004 and 2005 from 2,000 MTC to 1,500 MTC. This relationship can be better explained by Table 6.

Table 6: Carbon Emissions per MMBtu

Fuels	MT C per MMBtu ($x10^{-3}$)
#6	23
#2	19.6
Natural Gas	14.5

Table 6 shows the carbon emissions per MMBtu for each of the fuels used. Also from this table we can obtain percentage decreases when the different fuels are compared. If #6 oil is used as our baseline we can conclude that switching from #6 to #2 oil there will be a 14.7% decrease in carbon emissions. If the switch was made from #6 oil to Natural Gas then there would be 36.9% savings in carbon emissions.

There is a direct relationship between emissions and energy consumed. Figure 14 shows the energy consumed over the years 1987 to 2006.

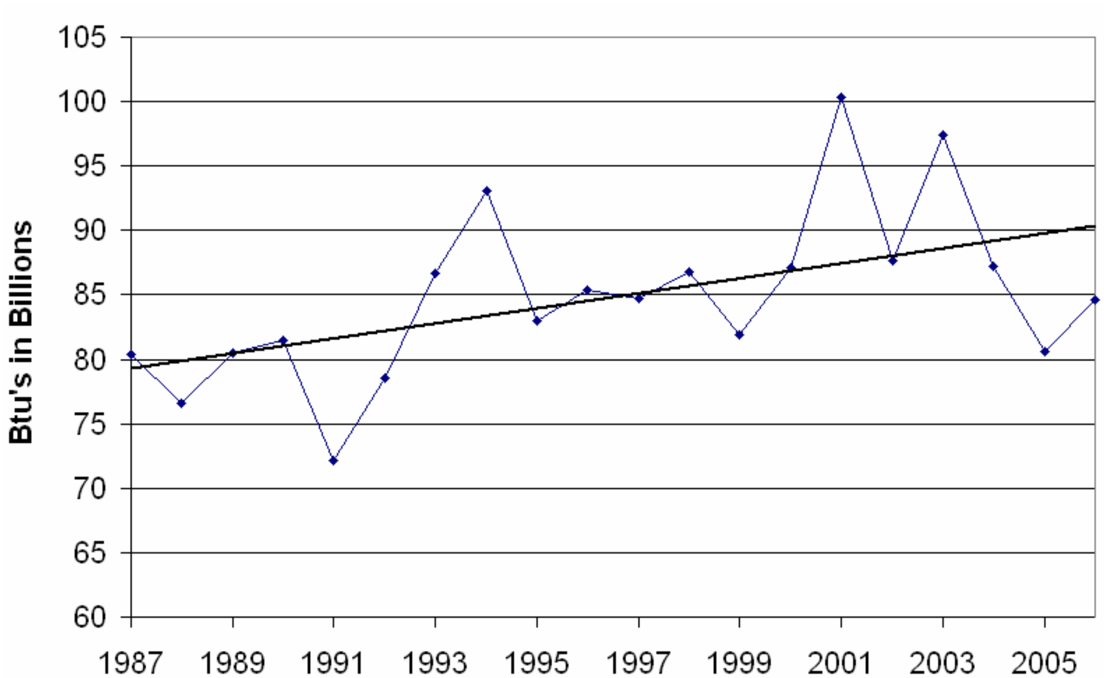


Figure 14: Energy Usage from 1987 to 2006 from Stationary Heating

As you can see the trend is steadily increasing. In 1987 the amount of Btu’s used was 80.4 Billion Btu’s and in 2006 there were 84.6 Billion Btu’s, an increase of 4.92%.

4.1.1 Two Year Comparison of Oil Consumption

To begin this analysis the data for the years 2002 and 2001 were plotted. The reason why these two years were chosen is because they are the most recent years for which we have data broken down monthly. In 2003 the computer system in the heating plant crashed causing monthly data to be lost for the years 2003 to 2006. In 2005 the plant switched from #6 oil to a combination of #2 oil and natural gas which makes analysis for these years harder. For both of these data sets, the amounts of oil burned for each of the winter months were provided by Bill

Grudzinski, who is the Lead Operating Engineer, which we then converted to Btu's. The data for 2002 and 2001 were then graphed to show the trend of how Btu's used over these months. Figure 15 shows this.

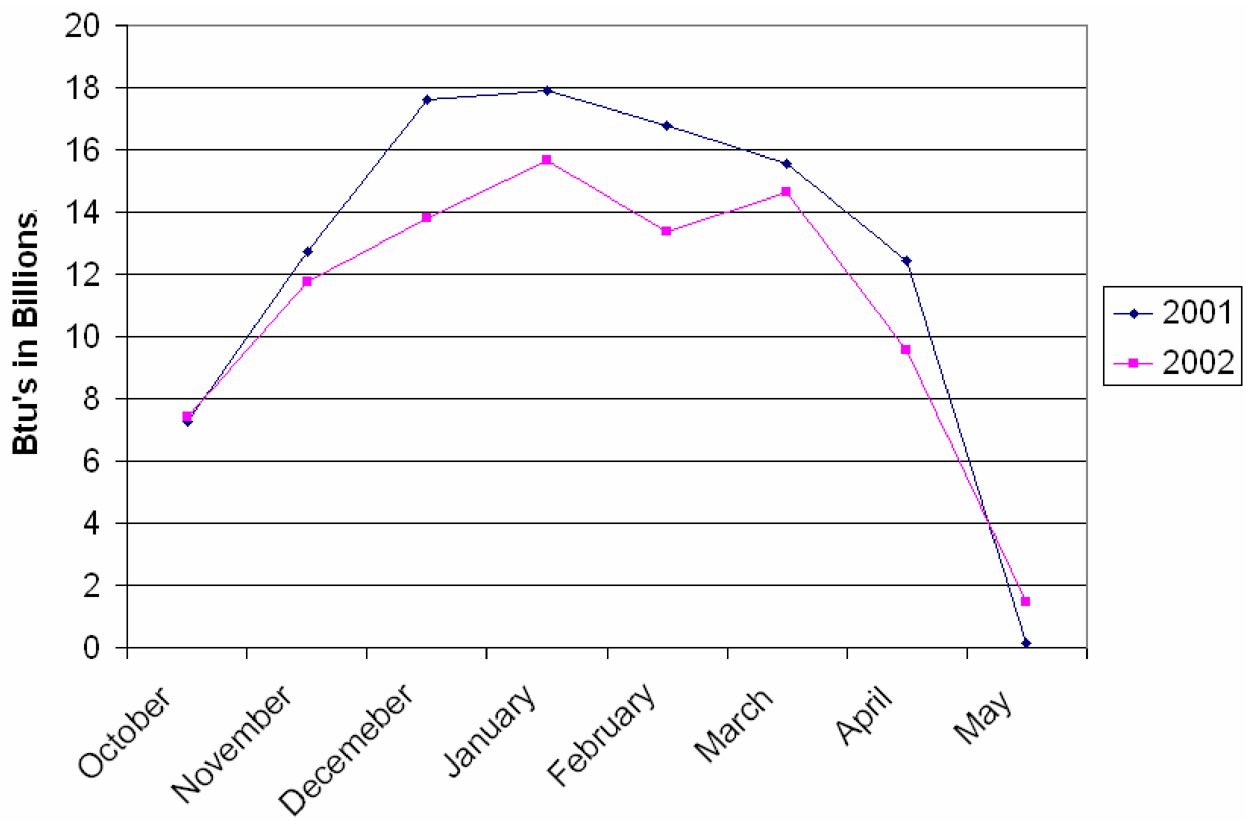


Figure 15: Billion Btu's Consumption for 2002 and 2001

Figure 15 shows that the trend for energy consumption over the winter months is fairly similar. In the beginning months, October and November the amount of energy used is steadily increasing. Then it begins to level off at around 17.5 Billion Btu's in 2001 and in 2002 it begins to level off at around 14.2 Billion Btu's. Then as winter begins to wine down the amount of Btu's consumed begins to drop off quickly.

4.1.2 Comparison of Fuels and Cost Analysis

For the years shown above WPI was burning #6 oil which is oil high in sulfur and carbon emissions when burned. In 2005 Worcester Polytechnic Institute changed their oil supply from #6 to #2 oil. From Table 6 we see that #2 oil produces 14.9% fewer emissions than #6. In 2005 WPI also began using natural gas as a source of heat. Table 7 and Table 8 show the total CO_2 emissions for #6 and #2 oil.

Table 7: Total CO_2 Emissions #6 Oil

Year	Gallons of Oil	#6 Oil Conversion Factor (MT C / Gal) x10^{-3}	#6 Total Emissions (MT of C)
2002	632,290	3.19	2,018
2001	723,686	3.19	2,309

Table 8: Total CO_2 Emissions #2 Oil

Year	Gallons of Oil	#2 Oil Conversion Factor (MT C / Gal) x10^{-3}	#2 Total Emissions (MT of C)
2002	632,290	2.72	1,723
2001	723,686	2.72	1,972

Table 7 shows the actual amount of oil that was consumed for the years 2001 and 2002 and the amounts of carbon produced. Table 8 shows these two years and how emissions would differ if #2 oil had been used. This data confirms what we saw in Table 6 that switching from #6 to #2 oil will reduce emissions by 14.7%. The difference between these emissions in 2002 was 295 Metric Tons of Carbon and in 2001 it was 337 Metric Tons of Carbon.

This analysis can be taken even further by comparing the emissions of oil to emissions of natural gas. Next we wanted to analyze the same years to find the amount of natural gas emissions that would have been needed to produce the same amount of energy as oil. The following steps show how we obtained the equivalent amount of natural gas needed to match the amount of oil consumed in the years 2002 and 2001.

$$\#\, gallons\ of\ oil \times \frac{138{,}691\ Btu}{1\ gallon\ of\ oil} = X\ Btus\ from\ oil$$

This equation gives us a total Btu number that a certain amount of burned oil produced. In order to calculate an equivalent number of emissions arising from burning natural gas, we wanted to see how many emissions would result from creating this same number of Btus but using natural gas.

$$X\ Btus \times \frac{53\ Kg\ CO_2}{1{,}000{,}000\ Btu} \times \frac{1\ Metric\ Ton\ CO_2}{1{,}000\ Kg\ CO_2} \times \frac{12\ Metric\ Tons\ Carbon}{44\ Metric\ Tons\ CO_2} = Metric\ Tons\ Carbon$$

Table 9 shown below shows the values for these calculations for the years of 2002 and 2001. Table 9 represents the equivalent amount of natural gas needed to burn to match the energy production of oil.

Table 9: Natural Gas Equivalents

Gallons of Oil	Btu per Gallon of Oil	Billion Btu Produced	Conversion Factor for Natural Gas (MT C / Billion Btu)	Total Emission for Natural Gas (MT of C)
632290	138691	87.69	14	1,268
723686	138691	100.37	14	1,451

From Table 9 it is important to comment on the amount of emissions that are produced by just using natural gas. When the amount for the year 2002 of #6 oil is compared to natural gas there is a significant different in emissions. In 2002, natural gas had emission of 1,268 Metric Tons of Carbon and the amount of Carbon produced by #6 oil, 2,018 Metric Tons of Carbon (Table 7). When these are compared there is a percent decrease in emissions by 37.17%, assuming that natural gas was the only thing used. So to produce the same amount of energy to heat the campus, natural gas is the best choice because of its low emissions.

Now we wanted to look at #2 oil, which is cleaner oil, and compare that to natural gas. The totals emissions for #2 oil for the year 2002 was 1,723 Metric Tons of Carbon and the natural gas total emissions was 1,268 Metric Tons of Carbon. When these two values are compared to see how much Carbon would be saved, it came out to be 26.42%. This shows that #2 oil is cleaner then #6 oil but still does not compare to natural gas.

There is an underlying issue of cost. The question arises, how much more would it cost to reduce these emissions? Table 10 provides a cost breakdown for the comparison of oil to natural gas.

Table 10: 2002 Cost Analyses for Oil and Natural Gas

Gallons of Oil	Dollars Per Gallon	Dollars Per Btu	Total Dollars for Oil
632,290	$1.77	$0.000013	$1,119,153.30
Therms of Natural Gas	**Dollars Per Therm**	**Dollars Per Btu**	**Total Dollars for Natural Gas**
876,929	$1.50	$0.000015	$1,315,393.99

Table 10 shows the cost of oil and natural gas for the year 2002 and the dollars per Btu. For the year 2002 the cost of oil was $1.1 Million and the cost of the equivalent use of energy for natural gas is $1.3 Million. The difference between these two values shows the extra cost that would be needed to reduce these emissions. This value is $196,240. This information is relevant because if we refer back to Table 8 and Table 9 we can see that the percent decrease in emissions would be 27%, if WPI was willing to spend $200,000 more a year.

As Worcester Polytechnic Institute continues to grow the amount of emissions will increase but there are many different measures that can be taken to reduce these emissions. The analysis that was just discussed shows that there are cleaner solutions to help lower emissions but when these cleaner solutions are implemented it will drive the cost up. The idea to reduce harmful emissions is a very difficult task because there are so many factors that contribute to these emissions. Factors that can be controlled, such as types of oil and natural gas, should be taken into consideration so that emissions can be lowered in years to come.

4.1.3 Overall Emissions as a result of Increased Building Space

Figure 16 shows the oil per square footage over the years 1987 to 2006 during which time WPI has been expanding. In 1989 Fuller Laboratories was constructed and in 2000 the Campus Center was built. Then in 2006 the Bartlett Center was built, but the square footage for that building was not provided to us by John Miller.

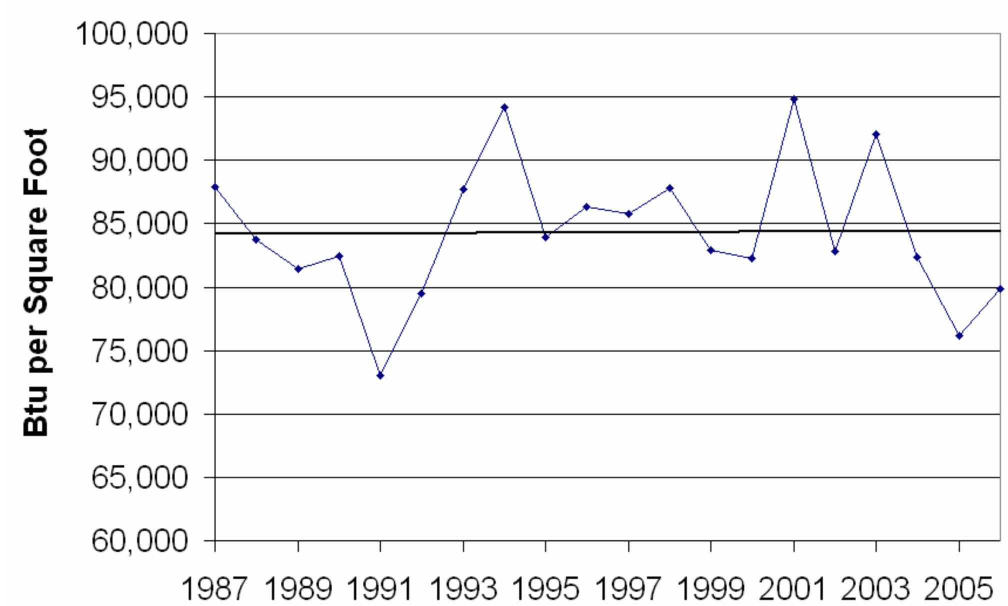


Figure 16: Btu's per square footage of building space

Figure 16 shows that the Btu's used per square foot of the campus have remained fairly constant over time. In the year 1989 Fuller Laboratories was constructed on campus. This new building increased the amount of Btu's needed to heat he campus because it was another source that was consuming energy. From Figure 16, WPI proves to be fairly constant over a long period of time with the amount of Btu's consumed per square foot. Then in the year 2000 the Campus Center was added which increased the amount of Btu's needed to heat the campus.

We have shown that overall energy consumption at WPI has increased steadily from 1987 to 2006 and as a result emissions have increased. However, this increase in emissions is a result of increased building space and the overall Btu's per square footage has remained constant over that period of time.

4.1.4 Heating Degree Days

Along with having data for the consumption of Btu's, the degree days were available as well. Having this data allows us to normalize the data so that it can be further analyzed. A degree day is defined by the equation:

$$Normalized\ Degree\ Day = \sum (65°F - Average\ Daily\ Temp.)$$

What this equation shows is that for each day of the month, throughout the entire year the average daily temperature was taken and then subtracted from the value of 65 degrees Fahrenheit and then each of those values were summed up. This mathematical equation would normalize that data so that it could be compared to other months of the year as well as comparing year to year how the temperature affects the amount of Btu's consumed. Figure 17 shows the use of energy per month when compared to how cold the months were.

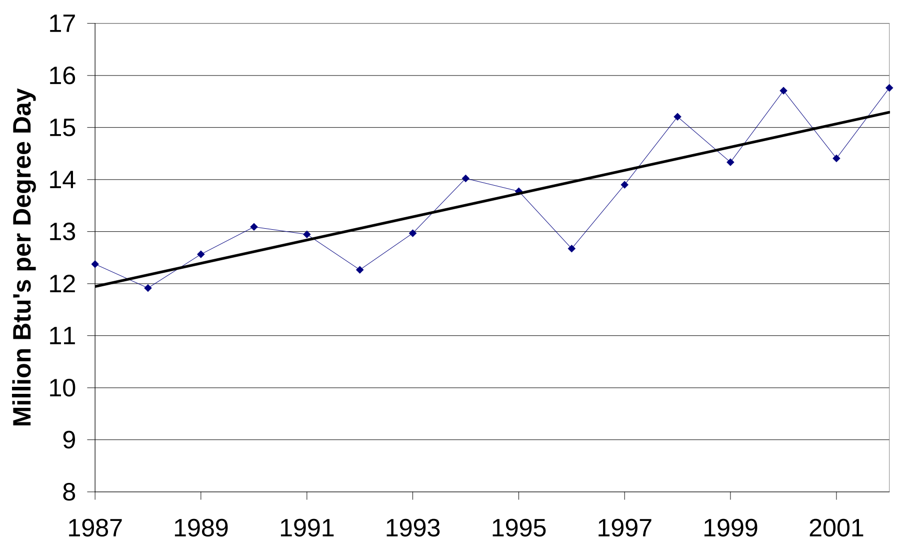


Figure 17: Million Btu's per Degree Day from 1987 to 2002

Figure 17 shows the steady increase in the amount of Btu's consumed per degree day over years 1987 to 2002.

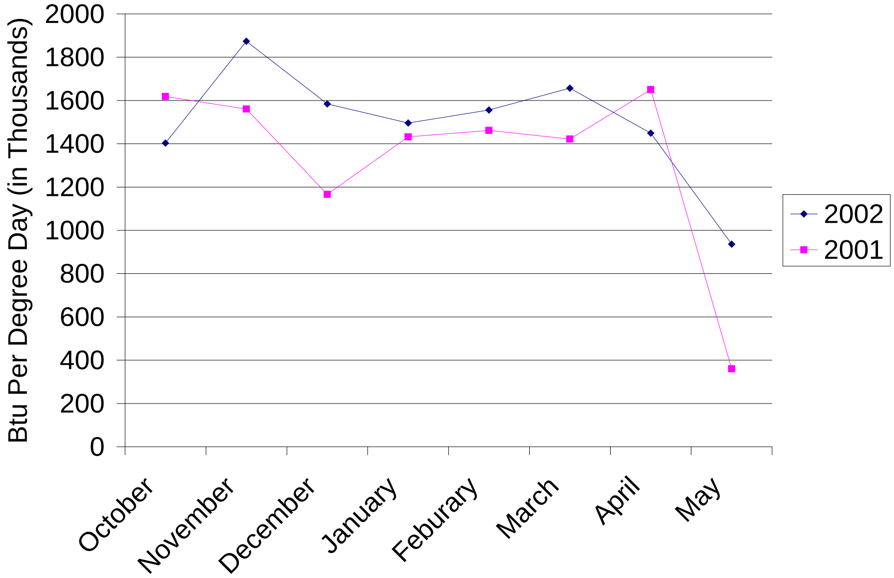


Figure 18: Million Btu's used per Degree Day for 2002 and 2001

Figure 18 shows the Btu's used per Degree Day from the years 2002 to 2001. From Figure 18 it is easy to say that the Btu's consumed per degree day is fairly constant with a few outliers shown. If the months from October to March are only focused on it shows a nice relationship that is constant. When we obtained the data from Bill Grudzinski, April of 2002 listed only 252 degree days. When we plotted this data we noticed a huge spike meaning that an extreme amount of oil was used for those few degree days. When we spoke with Mr. Grudzinski he was positive that must be a typing error. We looked on the Department of Commerce Website and found there to have been 652 degree days in April 2002, so it indeed was an error. Figure 18 uses the correct 652 degree days for April 2002.

4.2 Electricity Usage and Costs

Electricity is one of the main sources of emissions at WPI, accounting for 9,000 metric tons of CO_2 out of 20,000 metric tons of CO_2 from Figure 10 (45%). We wanted to plot the electricity usage by month from 1996 to 2006 so we could see the changes in usage by season.

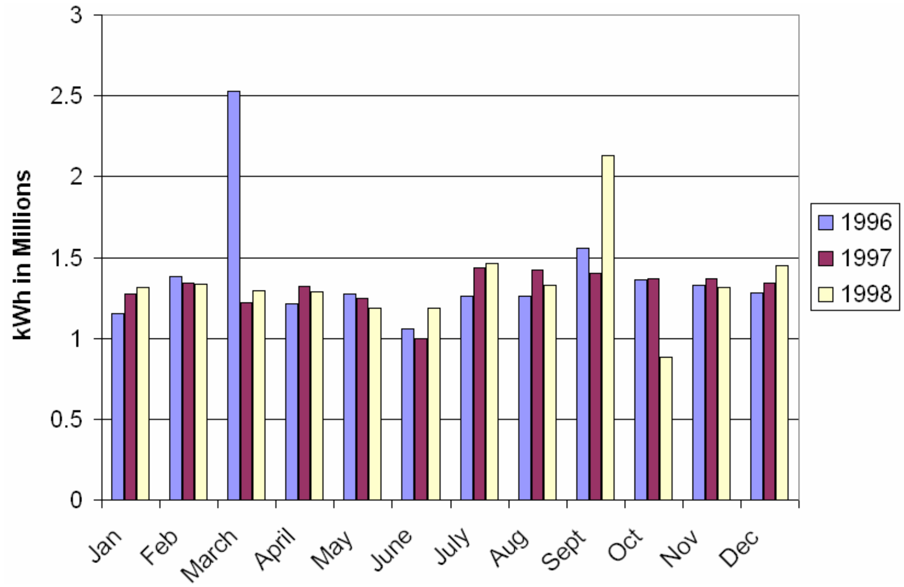


Figure 19: Total electricity usage from WPI's main meter 1996-1998

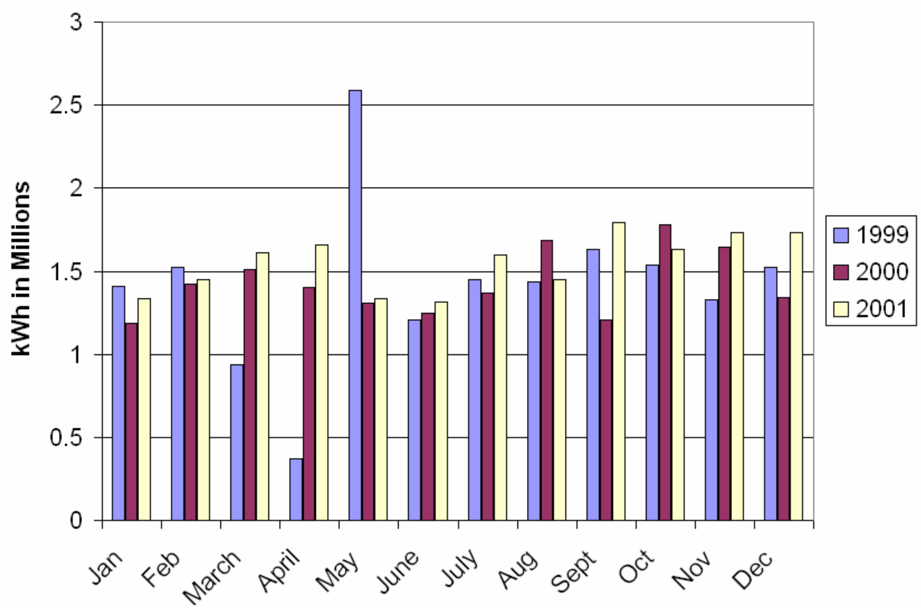


Figure 20: Total electricity usage from WPI's main meter 1999-2001

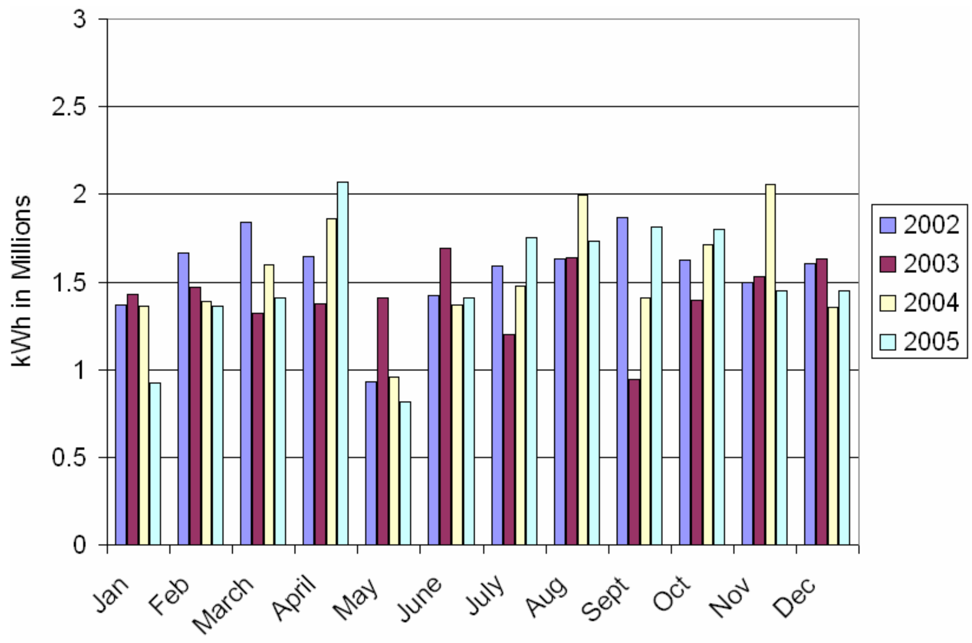


Figure 21: Total electricity usage from WPI's main meter 2002-2006

From Figure 19, Figure 20, and Figure 21 we see that electricity usage can fluctuate greatly from month to month, for example between April and May in 1999. This change is extreme and we feel this is due to the billing system at WPI which does not break down usages to exact months but rather on periods varying in length anywhere from 20 days to 40 days. This means that the May data could actually include usage from April or June. Any easy way to check that this happened would be to look the kWh usage per day (which could be obtained from the bills) and compare this value to the kWh/day for the same month in other years. Even though monthly totals can vary greatly, the overall yearly totals remain fairly constant.

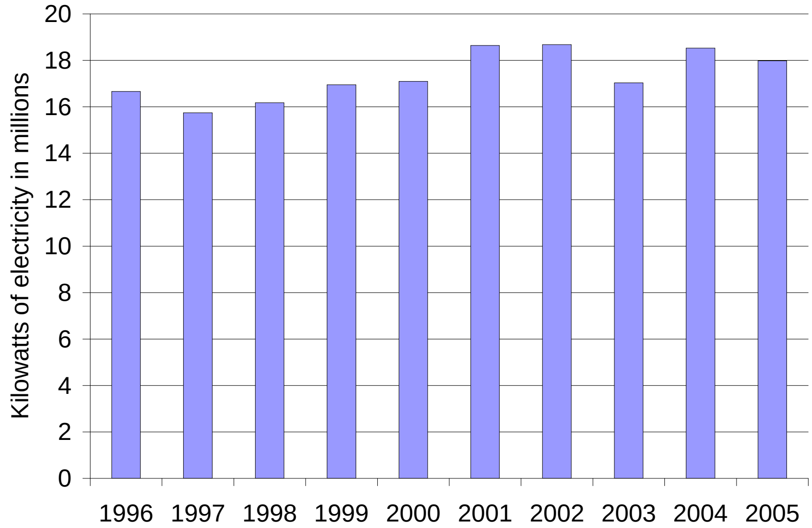


Figure 22: Total electricity consumption broken down by year

Since electricity is such a significant source of emissions, we broke it down by year going back to 1996 to show the emissions related only to electricity. To do this we used the same procedure as described in section 3.4.1 "Using our own spreadsheet".

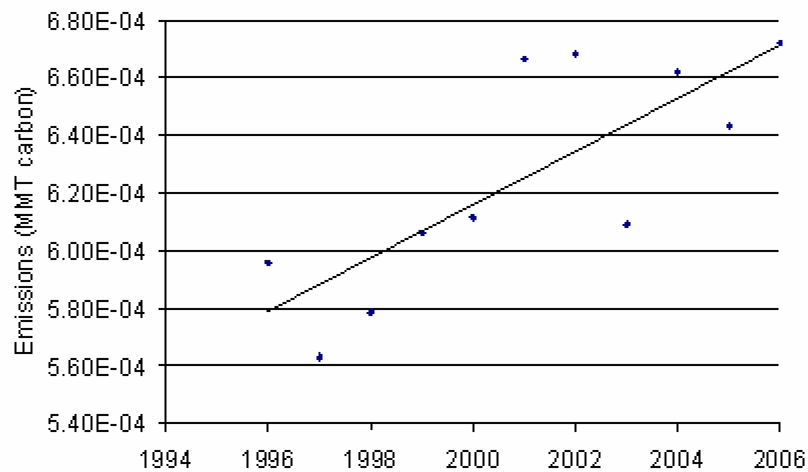


Figure 23: Electricity Emissions per Year

What we see in Figure 23 is disturbing because emissions have steadily increased, by 16% in 10 years. WPI needs to take action in order to assure that emissions due to electricity do not continue to climb at these current rates.

As we stated before, there are three electricity companies which we acquired data for that supply electricity to the Massachusetts area: National Grid, Direct Energy and Hess. Below is a breakdown of the three companies and the fuels they use to generate electricity. The National Grid data is from April 1, 2005 to March 31, 2006, the Direct Energy is from October 1, 2006 to December 31, 2006 and the Hess data is from 2005.

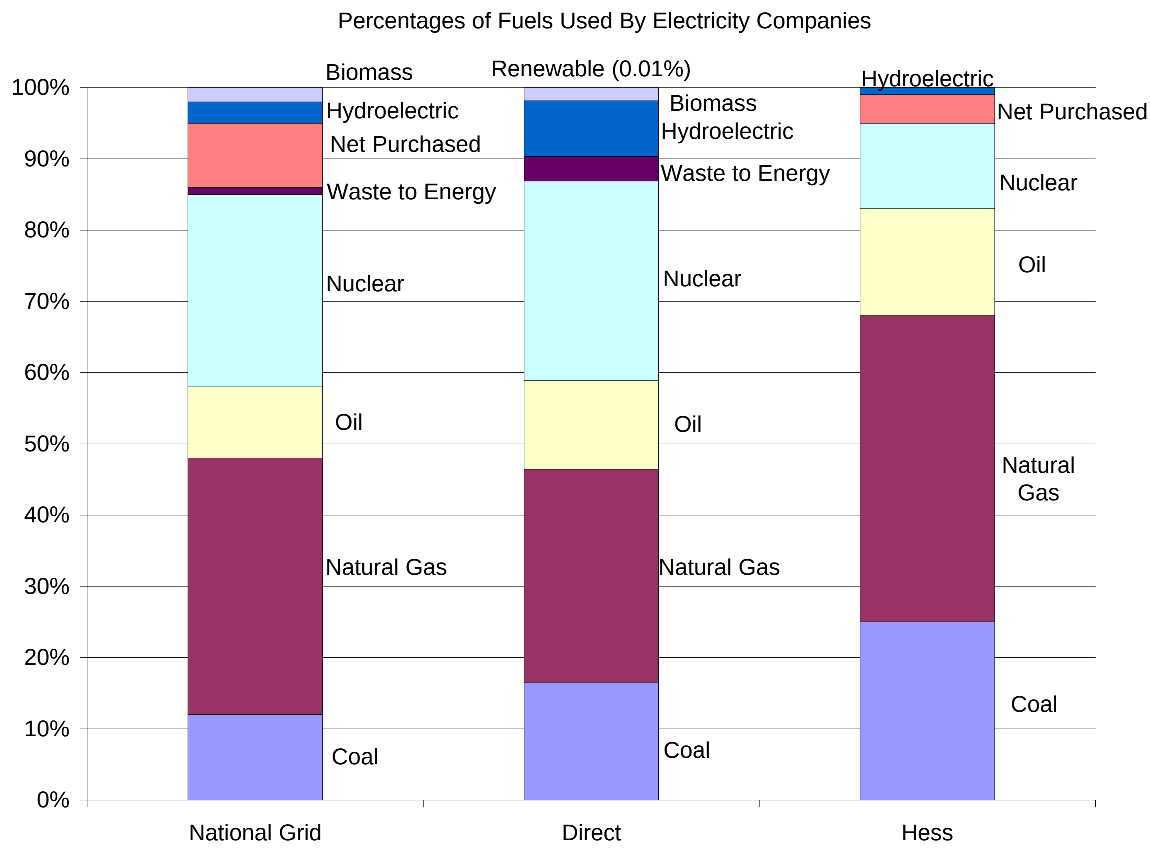


Figure 24: Breakdown of fuels used by 3 local companies to generate electricity

The three fuels we need to focus on from this graph are oil, natural gas and coal because those are the three that produce carbon emissions. From Figure 24 we would expect National Grid to be the cleanest source of electricity because it uses the smallest amounts of these three fuels. Direct Energy should be the next highest and finally Hess would be the worst.

Next we focused on the year 2006 to compare emissions and cost data between the three companies. It is important to compare the emissions per kWh for each company so that is what we did next by dividing the total emissions by the total electricity usage. In order to do this we used the spreadsheet we made (found in Appendix A) which breaks down the emissions generated by each fuel used for each electricity company. To get a total emissions number we added the MMTC of Coal, the MMTC of Oil and the MMTC for natural gas. For National Grid this was 6.72×10^{-4} MMTC. What we wanted to do next was compare the three electricity companies by looking at their overall emissions per kWh. We used the following equation.

$$\frac{6.72 \times 10^{-4}\, MMTC}{18795200\ kWh} = 3.58 \times 10^{-11}\ MMTC\ \ per\ kWh$$

For Direct Energy and Hess the values are 3.86×10^{-11} and 5.72×10^{-11} respectively with the same units which translates to a 7.3% difference for Direct Energy and a 37.4% for Hess.

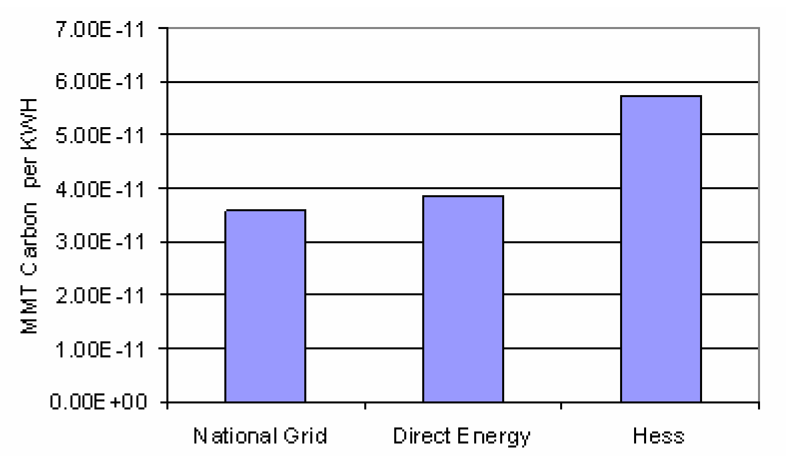


Figure 25: Million Metric Tons of Carbon emitted per kilowatt hour for each supplier

From John Miller we were able to obtain a set of electricity bills for the past year from National Grid and also obtained estimates of unit cost of electricity for National Grid and Direct Energy.

Table 11: Emissions and cost data for 2 suppliers in 2006

Company	MMTC per KWH (x10^-11)	Cost per KWH ($)	Cost of Electricity ($ year 2006)
National Grid	3.58	0.132	$2,480,966
Direct Energy	3.86	0.1327	$2,494,123

For the cost of Electricity column we multiplied the unit cost for each company by the electricity used for WPI's main meter which for 2006 was 19 Million kWh. We also used this data to compare the three companies and how WPI could reduce emissions by switching companies and the cost of doing so.

Table 12: Cost and results of switching from Direct Energy to National Gird

National Grid to Direct Energy	Extra Cost	Increased Emissions (MMTC per KWH)	Total Emissions Increased (MMTC)	Percentage of Emissions Increased
	$13,157	2.08E-09	5.31E-05	7.90%

The "Extra cost" column refers to how much money WPI would spend switching from National Grid to Energy a year. The "Increased Emissions" column refers to how many extra metric tons of carbon WPI would emit per kilowatt hour by using Direct Energy Grid instead of National Grid. "The Percentage of Emissions Increased" is self-explanatory and shows the amount we would increase by when we switch to Direct Energy.

From this analysis we can see that National Grid is a better electricity supplier for us to purchase electricity from. From the cost data we have access to we can estimate that WPI would save roughly $13,000 yearly by using National Grid and could also reduce emissions by about 8% by using this same company. We asked John Miller why WPI was switching from National Grid to Direct Energy and apparently WPI is part of a consortium of other universities that Direct Energy bid on and won.

When we looked at Middlebury College, a university in Vermont of similar population 2,300 compared to 3,300 at WPI they used 19.9 Million kWh in 2000 while WPI used 21.9 Million kWh in 2006. This means that the average student at Middlebury uses 8,652 kWh per year while the average WPI student uses only 6,636 kWh per year. We find this to be very surprising because WPI is a largely technical school which runs many computers and other machines requiring electricity.

4.3 Transportation Analysis

The transportation data is very difficult to analyze because it is very difficult to obtain credible values. The one thing we are certain of in the transportation sector is that our assumptions can greatly influence the emissions stemming from the transportation sector. It was shown in a graph in section 4.1 the emissions from transportation assuming each WPI community member drove 15 miles per trip for the specified number of days.

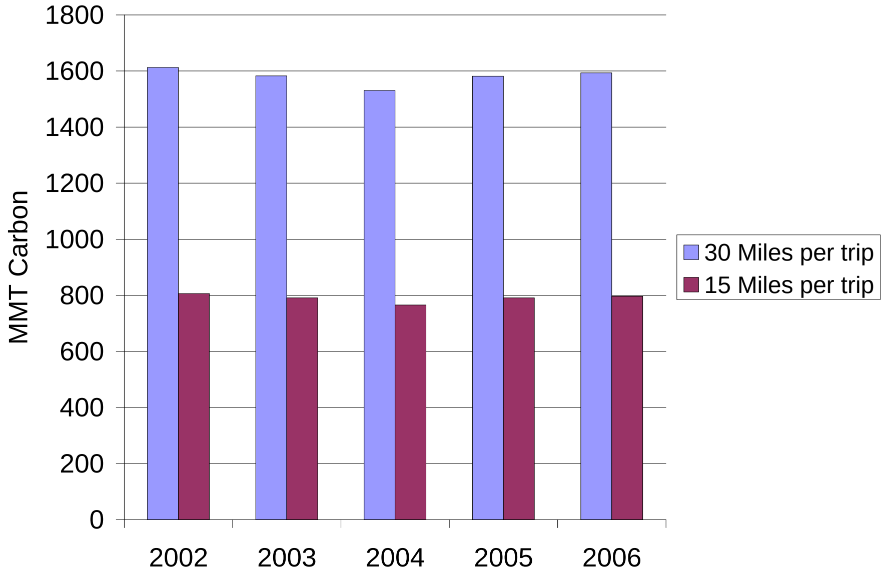


Figure 26: Difference in emissions from student transportation sector

We have shown here how much the emissions can increase by assuming that each student trip consisted of 30 miles instead of 15 miles. It can vary as much as 800 Metric tons of Carbon. Figure 26 does not include any faculty or staff transportation data; it serves only to show the magnitude of change our assumptions can make.

Chapter 5: Future Recommendations

Our project would not be complete if we did not give some explanation of what we believe are the future steps to completing our efforts and seeing it through. We believe that we have made a large stride towards our final goal, seeing that this is the first attempt that has been made to do this type of analysis at WPI. If our efforts are recognized and looked into further, possibley by another IQP group, then we believe that it could accurately track how WPI is at reducing greenhouse gas emissions.

Our project has used all the available information that we could find on campus. It has come from many different sources, as we have noted, and each source has data going back to different years. Some of the data is missing years or is estimated and this is one area or our project that we know needs improvement. We received decent electricity data at the start of our search. We continued to seek more, and found some scattered along the way but just as we were about to stop looking we received a data sheet from John Miller that was more helpful than anything we had obtained up to that point. In our data search we found lots of information, but whenever you are looking for data there is always more somewhere if you keep digging.

Along with recovering any more data that can be found, would be to create a better way to store the new data that is being created. In our research we have come to the conclusion that in many cases at WPI accurate records are not kept. Often a bill will come in and the accounting office will just pay it regardless if the bill is higher than the previous month. The bill could be higher due to a broken water pipe or improper operation of the boilers in the heating plant. If this data is tracked and paid attention to, it could potentially save WPI lots of money.

Our last section of our recommendations will be dedicated to simple recommendations to students, faculty and staff. Things like shutting off lights, computer screens, and heaters when not in use. If everyone actually followed these simple recommendations it could save WPI millions of dollars.

5.1.1 Searching for Data

Data is the most essential part of this project. Without data we would not be able to perform any type of analysis on WPI's past or current emission status. This data enables us to make comparisons to national averages and evaluate what areas on campus need the most improvement. Tools like the Clean Air – Cool Planet calculator are very helpful for storing this data and also performing an analysis.

The information that we gathered only allowed us to do a strong analysis for overall greenhouse gases for the past five years. We had data going as far back as 1987, but could only use these numbers for particular analyses. If we had all the information dating back that far we could have performed a much better overall analysis. Due to time restraints and a lack of assistance from some departments on campus we were unable to attain all the information that would like to of have.

Here are a few future recommendations when looking for information:

- Any information that you receive, write down when you got it and whom you go it from.

- Keep a log of any meetings, emails, contacts, or phone conversations that you have.
- Keep all of your data in one easily-accessible place. Scanning all documents that you receive, email them to anyone who will benefit from them and keep them in a folder designated just for data collected will help.
- Thank everyone for any help or data that you get, you may need their assistance again.
- If you do not receive something that you have been waiting for, send a friendly reminder, they may have forgotten.
- If you don’t find what you’re looking for, keep digging! It’s probably out there somewhere.

The search for recovering specific data is never easy. It is one that takes a lot of time and effort, and even then you may not get all the results you were looking for. Organize your time and keep yourself busy while you are awaiting new information. If you look hard enough and deep enough you will usually find what you are looking for.

5.1.2 Keeping Better Records

Looking for data is never easy, but it becomes significantly less stressful and complicated when good records are kept. If data is easily accessible and well-organized then the time it takes to find it is minimized considerably. The data may not always be in the units or the form that you need it, but it’s much better to have that information than none at all.

In our search for data at WPI we have noticed two main problems. The first problem is that data is very spread out and hard to find. There is no standard of how things are organized and each department does things differently. Some departments started to make excel spreadsheets with all of its data, but did not follow through every year. Others would just take what they had put it in a filing cabinet and not know where things were when they were trying to locate them.

Even though obtaining valuable information was difficult for several departments, some actually had very detailed organized data sheets. The best department, as far as keeping good records, was the heating plant. The department head, Bill Grudzinski, had set up excel spreadsheets that would keep track of all of the key information from the plant. It was updated timely by the employees and this information was used to look for any irregularities in the plant. If something was out of the ordinary he knew where to find the problem and fix it as soon as possible.

Mr. Grudzinski ran into a problem though. When the heating plant was upgraded to the new plant that we run on today, he had to learn the new system. What he did not realize was that when the computers crashed, he lost all of the data that he thought was being saved. Once he noticed this problem he got back to his old ways of record keeping and hasn't had a problem since. Because of this problem though, there was a significant amount of lost data spanning nearly three years.

Record keeping is never easy, but you need to find one method that is effective and works for you. Here are some future recommendations for record keeping in future years:

- Keep all records in one, easily-accessible place.
- Be consistent with time; don't start keeping records of each day then switch to each month, do whatever is needed to do a good analysis.
- Be consistent with units; don't start keeping records in gallons then switch to liters, numbers will look different when they could be the same. See the attached sheets in the appendix to see recommended organization for each department.
- Be detailed with what you keep track of, you may need something down the road that you didn't think was important.
- Update records consistently; update them daily or monthly or whenever needed, getting behind only complicates things.
- Always double check data to look for a wrong input or out of trend data, noticing an outlier could be due to broken equipment.

Keeping good records is not easy and can be a huge inconvenience most of the time. However it is keeping track of these records that can lead to the discovery of a problem in a system. If a problem is discovered and fixed sooner than later it will avoid a waste of money, products and ultimately emissions. If there is no one in the department with enough time to keep these records, a work study student could be assigned to help with this process. These records will help future faculty, staff and students whether doing a project like this or the design of a new building. Good data logging is one of those things that no one wants to do, but if it is done right than if can be very helpful to have later on.

5.1.3 Power Saving Recommendations

Wasted energy is one of the biggest problems in the world today. It is difficult to regulate people's waste of energy such as leaving lights or televisions on when not being used. If things like this could be controlled then a tremendous amount of energy could be saved in the United States alone. If every American home changed out just five high-use light fixtures or the bulbs in them with ones that have earned the ENERGY STAR, each family would save about $60 every year in energy costs, and together we'd save about $6.5 billion each year in energy costs and prevent greenhouse gases equivalent to the emissions from more than 8 million cars. It is things like this that could significantly reduce greenhouse gas emissions and prevent things like global warming.

5.1.4 Student Recommendations

It is much easier to tell a homeowner who can save money by doing certain things than it is to tell a college student. Students at WPI do not have to directly pay for their electricity and heat so they do not care if they are wasting it. WPI has tried in the past to try and make students pay their own electric bill to reduce costs and emissions, but it is too difficult to collect from the students every month. This electric and heating bill is tacked on to the already high cost of living on campus. Students will leave their lights on when they are not in the room or turn the heat all the way up and open a window. Habits like this are costing WPI lots of money and in turn raise the cost of living on campus through the roof.

Here is a list of recommendations that students could do to lower the cost of living on campus and lower greenhouse gas emissions by WPI:

- Turn lights off when leaving the room for more than 10 minutes, lighting usually accounts for about 25% of our electrical use.
- Use compact fluorescent lights for any personal lights you have, they lasts ten times as long and save a lot of energy.
- Make sure your computer goes to sleep mode, a computer will use 80% less energy when in sleep mode.
- Turn your screen computer screen if no in use for 15 minutes or more, it accounts for 62.5% of your computers total energy use. A screen saver does not actually save any energy.
- Turn off any televisions or stereos when not in use.
- Keep thermostat around 68 degrees plus or minus 3 degrees. If you are not comfortable try adjusting your wardrobe before your thermometer, this will have a more immediate effect anyways.
- Keep furniture and other objects from obstructing the heaters to allow good flow.
- Do not blast your heat and open the window, this is a huge waste of heat and is very inefficient.
- Open your blinds during the day to let the sunlight in to heat the room and close them at night to keep heat in.
- Unplug all appliances when going home for break, don’t leave refrigerators plugged in to keep a couple of drinks cold.
- Recycle, this decreases the amount of solid waste WPI produces, which is burned in mass incinerators.

There are numerous more tips that we could list, but these are the ones we feel are most important and would reduce electricity costs and greenhouse gas emissions the most. These are all very simple things that do not take much effort to do, but are often ignored by students because they do not see any difference whether they do them or not. These things should be at least advertised in the dorms and the RAs should attempt to direct students to following these habits. Things like this would save WPI millions of dollars and reduce emissions immensely.

5.1.5 Faculty and Staff Recommendations

Faculty and staff can follow the same techniques at home and save themselves lots of money on their energy costs. This would not affect WPI's emissions or energy costs, but there are ways that they can help. WPI could save a significant amount of money if faculty and staff did a few simple things as well.

There are clearly not as many things that professors could do, but here are a few:

- Turn off lights when leaving a classroom, if there is a class in the same room immediately after that professor can turn them back on. This is especially important when they know they are the last professor in that classroom.
- Use the dimmer lights when possible. If it is a sunny day use the natural sunlight to light the room and turn the lights down or turn half of them off.
- Turn the heat down and shut the door and blinds. If a professor knows they are the last to use that room for the day, closing the door and turning the heat down will save a tremendous amount of heating costs.
- Turn off any other electrical appliances, computers, televisions or projectors. Once again if a professor knows they are the last to use the room, turning these appliances off will reduce energy costs.
- Turn off lights and heat in personal offices when leaving for the night. Also keep air conditioners to a reasonable temperature.

There are things that the staff at WPI could do. These ideas include the electrical appliances and heating systems that are actually used at WPI. Choosing the right appliances can save lots of money. These ideas include:

- Buy Energy Star appliances, such as computer monitors, printers, refrigerators and stereos.
- Replace any regular light bulbs with compact fluorescent lights.
- Buildings that run off electrical heat should switch to an alternate source. Electric heat is the most expensive and inefficient type of heating system.
- If there are five computer labs open with a few students in each one, close a couple of them and get the students to use the more common one.
- When constructing new buildings make them to LEED standard.

There are many more things that could be listed, but if just these things were done it would lead to hefty energy savings and reduction of greenhouse gas emissions. Some of these things may cost more initially, but will end up saving WPI money in the long run. Making these changes slowly will lead to a greener and most cost efficient WPI.

Chapter 6: Conclusion

The purpose of our project is to inform WPI and its community about its effects on the environment. All the energy that is being wasted can be prevented and with help from the policy group, we are hoping to reduce that. We can do our best to inform the community, but ultimately it is up to them to do what is right to reduce energy costs and emission rates.

Our project is an enormous step in the right direction towards doing an analysis of WPI's current and past emissions. Since nothing like this has been done in the past, we believe that we have accomplished a great deal. With the results that we have come up with and the future recommendations that we have given, we believe that this project can lead to great things.

The main concepts that were accomplished during this project are as follows:

- Overall WPI emissions have decreased since changing from #6 oil to #2 oil and natural gas for heating; however it is slowing beginning to increase again

- As a result of switching oils for heating needs, in the years 2004 and 2005 there was a decrease in emissions from 2,000 MT Carbon to 1,500 MT Carbon, respectively, which is a 27% reduction in emissions.
    - Even though emissions decreased since 2004, the energy demand has increased. In 1987 the amount of Btu's used was 80,413,735,255 Btu's and in 2006 there were 84,577,747,282 Btu's used, is an increase of 4.92%.
    - If WPI is willing to increase their budget by about $200,000 yearly, then the emissions produced would greatly decrease by 26.62% per year compared to oil.
- Electricity usage has increased from 16,662,380 kWh in 1996 to 18,799,200 kWh in 2006 which is an increase of 11.4%.
    - After analyzing the three different companies; National Grid, Direct Energy, and Hess, National Grid produces the fewest emissions per kWh at 3.58×10^{-5} Metric Tons of Carbon per kWh.
    - By using National Grid, WPI could reduce emissions 7.9% a year and save $13,157 a year.

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8 Appendix A

8.1 National Grid Data

Chart of Emissions (MMT Carbon / kWh)												
Coal	Natural Gas	Oil										
8.87E-11	4.94E-11	7.34E-11										
National Grid Data												
Year	kWh Used	Fuel Mix										
		% Coal	kWh from fuel	MMT from Coal	% Natural Gas	kWh from fuel	MMT from Natural Gas	% Oil	kWh from fuel	MMT from Oil	% Nuclear	
1996	16662380	0.12	1999485.6	1.77E-04	0.36	5998457	2.96E-04	0.1	1666238	1.22E-04	0.27	
1997	15742320	0.12	1889078.4	1.68E-04	0.36	5667235	2.80E-04	0.1	1574232	1.16E-04	0.27	
1998	16178640	0.12	1941436.8	1.72E-04	0.36	5824310	2.88E-04	0.1	1617864	1.19E-04	0.27	
1999	16950240	0.12	2034028.8	1.80E-04	0.36	6102086	3.01E-04	0.1	1695024	1.24E-04	0.27	
2000	17097840	0.12	2051740.8	1.82E-04	0.36	6155222	3.04E-04	0.1	1709784	1.25E-04	0.27	
2001	18638880	0.12	2236665.6	1.98E-04	0.36	6709997	3.31E-04	0.1	1863888	1.37E-04	0.27	
2002	18681600	0.12	2241792	1.99E-04	0.36	6725376	3.32E-04	0.1	1868160	1.37E-04	0.27	
2003	17033280	0.12	2043993.6	1.81E-04	0.36	6131981	3.03E-04	0.1	1703328	1.25E-04	0.27	
2004	18513360	0.12	2221603.2	1.97E-04	0.36	6664810	3.29E-04	0.1	1851336	1.36E-04	0.27	
2005	17987760	0.12	2158531.2	1.91E-04	0.36	6475594	3.20E-04	0.1	1798776	1.32E-04	0.27	
2006	18795200	0.12	2255424	2.00E-04	0.36	6766272	3.34E-04	0.1	1879520	1.38E-04	0.27	

8.1.1 National Grid Data Continued

kWh from fuel	MMT from Nuclear	% Waste to energy	kWh from fuel	MMT from W to E	% Net Purchased	kWh from fuel	MMT from Net Purchased	% Hydro-electric	kWh from fuel
4498842.6	0	0.01	166623.8	0	0.09	1499614	0.0001057	0.03	499871.4
4250426.4	0	0.01	157423.2	0	0.09	1416809	9.989E-05	0.03	472269.6
4368232.8	0	0.01	161786.4	0	0.09	1456078	0.0001027	0.03	485359.2
4576564.8	0	0.01	169502.4	0	0.09	1525522	0.0001075	0.03	508507.2
4616416.8	0	0.01	170978.4	0	0.09	1538806	0.0001085	0.03	512935.2
5032497.6	0	0.01	186388.8	0	0.09	1677499	0.0001183	0.03	559166.4
5044032	0	0.01	186816	0	0.09	1681344	0.0001185	0.03	560448
4598985.6	0	0.01	170332.8	0	0.09	1532995	0.0001081	0.03	510998.4
4998607.2	0	0.01	185133.6	0	0.09	1666202	0.0001175	0.03	555400.8
4856695.2	0	0.01	179877.6	0	0.09	1618898	0.0001141	0.03	539632.8
5074704	0	0.01	187952	0	0.09	1691568	0.0001193	0.03	563856

MMT from Hyrdro-electric	% Biomass	kWh from fuel	MMT from Biomass	Total MMT CO2
0	0.02	333247.6	0	7.02E-04
0	0.02	314846.4	0	6.63E-04
0	0.02	323572.8	0	6.81E-04
0	0.02	339004.8	0	7.14E-04
0	0.02	341956.8	0	7.20E-04
0	0.02	372777.6	0	7.85E-04
0	0.02	373632	0	7.87E-04
0	0.02	340665.6	0	7.17E-04
0	0.02	370267.2	0	7.80E-04
0	0.02	359755.2	0	7.57E-04
0	0.02	375904	0	7.91E-04

8.2 Direct Energy Data

Year	kWh Used	Fuel Mix									
		% Coal	kWh from fuel	MMT from Coal	% Natural Gas	kWh from fuel	MMT from Natural Gas	% Oil	kWh from fuel	MMT from Oil	% Nuclear
1996	16662380	0.0806	1342987.8	1.19E-04	0.3629	6046778	2.99E-04	0.12	1999486	1.47E-04	0.3452
1997	15742320	0.0806	1268831	1.13E-04	0.3629	5712888	2.82E-04	0.12	1889078	1.39E-04	0.3452
1998	16178640	0.0806	1303998.4	1.16E-04	0.3629	5871228	2.90E-04	0.12	1941437	1.42E-04	0.3452
1999	16950240	0.0806	1366189.3	1.21E-04	0.3629	6151242	3.04E-04	0.12	2034029	1.49E-04	0.3452
2000	17097840	0.0806	1378085.9	1.22E-04	0.3629	6204806	3.07E-04	0.12	2051741	1.51E-04	0.3452
2001	18638880	0.0806	1502293.7	1.33E-04	0.3629	6764050	3.34E-04	0.12	2236666	1.64E-04	0.3452
2002	18681600	0.0806	1505737	1.34E-04	0.3629	6779553	3.35E-04	0.12	2241792	1.64E-04	0.3452
2003	17033280	0.0806	1372882.4	1.22E-04	0.3629	6181377	3.05E-04	0.12	2043994	1.50E-04	0.3452
2004	18513360	0.0806	1492176.8	1.32E-04	0.3629	6718498	3.32E-04	0.12	2221603	1.63E-04	0.3452
2005	17987760	0.0806	1449813.5	1.29E-04	0.3629	6527758	3.22E-04	0.12	2158531	1.58E-04	0.3452
2006	18795200	0.0806	1514893.1	1.34E-04	0.3629	6820778	3.37E-04	0.12	2255424	1.65E-04	0.3452

8.2.1 Direct Energy Data Continued

kWh from fuel	MMT from Nuclear	% Waste to energy	kWh from fuel	MMT from W to E	% Hydro-electric	kWh from fuel	MMT from Hydro-electric	% Renewable
5751853.6	0	0.0335	558189.7	0	0.0398	663162.7	0	0.012
5434248.9	0	0.0335	527367.7	0	0.0398	626544.3	0	0.012
5584866.5	0	0.0335	541984.4	0	0.0398	643909.9	0	0.012
5851222.8	0	0.0335	567833	0	0.0398	674619.6	0	0.012
5902174.4	0	0.0335	572777.6	0	0.0398	680494	0	0.012
6434141.4	0	0.0335	624402.5	0	0.0398	741827.4	0	0.012
6448888.3	0	0.0335	625833.6	0	0.0398	743527.7	0	0.012
5879888.3	0	0.0335	570614.9	0	0.0398	677924.5	0	0.012
6390811.9	0	0.0335	620197.6	0	0.0398	736831.7	0	0.012
6209374.8	0	0.0335	602590	0	0.0398	715912.8	0	0.012
6488103	0	0.0335	629639.2	0	0.0398	748049	0	0.012

kWh from fuel	MMT from Renewable	% Biomass	kWh from fuel	MMT from Biomass	Total MMT
199948.6	0	0.006	99974.28	0	5.65E-04
188907.8	0	0.006	94453.92	0	5.33E-04
194143.7	0	0.006	97071.84	0	5.48E-04
203402.9	0	0.006	101701.4	0	5.74E-04
205174.1	0	0.006	102587	0	5.79E-04
223666.6	0	0.006	111833.3	0	6.31E-04
224179.2	0	0.006	112089.6	0	6.33E-04
204399.4	0	0.006	102199.7	0	5.77E-04
222160.3	0	0.006	111080.2	0	6.27E-04
215853.1	0	0.006	107926.6	0	6.09E-04
225542.4	0	0.006	112771.2	0	6.37E-04

8.3 Hess Data

Year	kWh Used	Fuel Mix																		
		% Coal	kWh from fuel	MMT from Coal	% Natural Gas	kWh from fuel	MMT from Natural Gas	% Oil	kWh from fuel	MMT from Oil	% Nuclear	kWh from fuel	MMT from Nuclear	% Net Purchased	kWh from fuel	MMT Net Purchased	% Hydro-electric	kWh from fuel	MMT from Hydro-electric	Total MMT
1996	16662380	0.25	4165595	3.69E-04	0.43	7164823	3.54E-04	0.15	2499357	1.83E-04	0.12	1999485.6	0	0.04	666495.2	5E-05	0.01	166623.8	0	9.54E-04
1997	15742320	0.25	3935580	3.49E-04	0.43	6769198	3.34E-04	0.15	2361348	1.73E-04	0.12	1889078.4	0	0.04	629692.8	4E-05	0.01	157423.2	0	9.01E-04
1998	16178640	0.25	4044660	3.59E-04	0.43	6956815	3.44E-04	0.15	2426796	1.78E-04	0.12	1941436.8	0	0.04	647145.6	5E-05	0.01	161786.4	0	9.26E-04
1999	16950240	0.25	4237560	3.76E-04	0.43	7288603	3.60E-04	0.15	2542536	1.87E-04	0.12	2034028.8	0	0.04	678009.6	5E-05	0.01	169502.4	0	9.70E-04
2000	17097840	0.25	4274460	3.79E-04	0.43	7352071	3.63E-04	0.15	2564676	1.88E-04	0.12	2051740.8	0	0.04	683913.6	5E-05	0.01	170978.4	0	9.79E-04
2001	18638880	0.25	4659720	4.13E-04	0.43	8014718	3.96E-04	0.15	2795832	2.05E-04	0.12	2236665.6	0	0.04	745555.2	5E-05	0.01	186388.8	0	1.07E-03
2002	18681600	0.25	4670400	4.14E-04	0.43	8033088	3.97E-04	0.15	2802240	2.06E-04	0.12	2241792	0	0.04	747264	5E-05	0.01	186816	0	1.07E-03
2003	17033280	0.25	4258320	3.78E-04	0.43	7324310	3.62E-04	0.15	2554992	1.87E-04	0.12	2043993.6	0	0.04	681331.2	5E-05	0.01	170332.8	0	9.75E-04
2004	18513360	0.25	4628340	4.10E-04	0.43	7960745	3.93E-04	0.15	2777004	2.04E-04	0.12	2221603.2	0	0.04	740534.4	5E-05	0.01	185133.6	0	1.06E-03
2005	17987760	0.25	4496940	3.99E-04	0.43	7734737	3.82E-04	0.15	2698164	1.98E-04	0.12	2158531.2	0	0.04	719510.4	5E-05	0.01	179877.6	0	1.03E-03
2006	18795200	0.25	4698800	4.17E-04	0.43	8081936	3.99E-04	0.15	2819280	2.07E-04	0.12	2255424	0	0.04	751808	5E-05	0.01	187952	0	1.08E-03

You will notice that all the % fuel data are the same from year to year. This is because we could only obtain data for 1 year.

This is explained in section 3.2.1

9 Appendix B

9.1 Energy Consumption in Btu's broken down by year and month for Oil

Energy Used in Btu's								
	1987	1988	1989	1990	1991	1992	1993	1994
October	5,085,937,661	6,139,018,424	6,751,477,880	6,189,363,257	3,030,259,659	5,222,270,914	4,647,812,792	8,156,417,710
November	10,403,350,601	8,948,482,011	8,852,785,221	9,979,233,523	8,937,802,804	9,624,045,872	9,016,995,365	11,098,885,966
Decemeber	14,403,892,496	11,555,456,738	11,733,952,055	15,877,900,444	13,291,174,603	14,420,535,416	15,070,164,060	13,668,275,432
January	13,950,095,544	14,692,508,467	12,234,487,874	12,950,272,125	13,768,549,025	13,300,466,900	12,963,309,079	18,551,169,469
February	13,772,848,446	12,856,933,082	13,934,978,225	12,784,675,071	12,210,910,404	13,016,705,114	14,374,073,931	16,014,927,152
March	10,541,902,910	10,552,582,117	12,782,872,088	11,620,918,890	11,342,843,435	12,544,878,332	14,110,422,340	15,225,359,289
April	8,695,925,700	8,241,296,602	9,603,380,913	10,332,756,882	7,335,921,754	10,052,739,753	10,920,945,413	8,707,159,671
May	3,559,781,897	3,627,463,105	4,565,014,265	1,780,098,985	2,278,277,057	411,912,270	5,561,370,409	1,672,752,151
Total	80,413,735,255	76,613,740,546	80,458,948,521	81,515,219,177	72,195,738,741	78,593,554,571	86,665,093,389	93,094,946,840

	1995	1996	1997	1998	1999	2000	2001	2002
October	5,494,660,038	5,358,881,549	6,198,100,790	5,171,926,081	4,901,894,704	5,026,300,531	7,262,415,524	7,431,895,926
November	9,634,586,388	11,728,265,724	11,924,236,107	12,040,320,474	9,968,138,243	13,365,096,906	12,723,928,413	11,767,515,277
Decemeber	13,145,549,053	15,285,828,565	13,626,668,132	15,061,842,600	12,241,283,733	13,365,096,906	17,589,208,693	13,816,120,038
January	14,576,840,173	15,864,863,490	14,885,150,266	21,548,559,361	16,326,843,211	16,792,151,516	17,899,044,387	15,639,767,997
February	15,199,978,836	13,535,686,836	12,835,019,904	12,859,706,902	13,516,547,478	14,487,939,242	16,760,252,586	13,348,315,295
March	13,471,750,285	14,204,732,220	13,292,561,513	13,355,665,918	13,264,407,240	13,482,152,110	15,552,531,358	14,655,755,352
April	10,432,337,020	8,360,432,171	9,751,502,901	5,812,123,737	9,380,227,094	10,575,050,059	12,435,451,133	9,573,146,275
May	1,025,203,872	1,009,531,789	2,225,713,168	931,448,756	2,290,343,174	23,161,397	145,902,932	1,460,416,230
Total	82,980,905,665	85,348,222,344	84,738,952,781	86,781,593,829	81,889,684,877	87,116,948,667	100,368,735,026	87,692,932,390

10 Appendix C

10.1 Electricity Records

	Calendar Year 1996				Calendar Year 1997				Calendar Year 1998		
Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh
January	491760	659280	1151040	January	513360	757920	1271280	January	547200	765360	1312560
February	597840	780960	1378800	February	591840	747600	1339440	February	605760	727920	1333680
March	548640	633840	2529840	March	559440	659280	1218720	March	570720	723600	1294320
April	568800	644400	1213200	April	575760	746640	1322400	April	610800	674400	1285200
May	579840	696240	1276080	May	596880	648960	1245840	May	560160	627360	1187520
June	466800	592080	1058880	June	426960	571440	998400	June	541440	646320	1187760
July	576620	687360	1263980	July	653040	785280	1438320	July	657600	805680	1463280
August	586080	675360	1261440	August	618720	805440	1424160	August	610800	720480	1331280
Sept	667200	888720	1555920	September	618480	786960	1405440	September	965760	1165680	2131440
October	616800	745440	1362240	October	636720	735120	1371840	October	371520	514080	885600
November	546480	780480	1326960	November	582720	783360	1366080	November	566880	747360	1314240
December	571200	712800	1284000	December	618720	721680	1340400	December	677760	774000	1451760
			16662380				15742320				16178640

10.1.1 Electricity Records Continued

	Calendar Year 1999				Calendar Year 2000				Calendar Year 2001		
Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh
January	578640	831120	1409760	January	545520	644160	1189680	January	553920	784080	1338000
February	646560	876000	1522560	February	645960	766320	1421280	February	657120	794880	1452000
March	425280	513360	938640	March	624240	886320	1510560	March	664080	944160	1608240
April	184560	186000	370560	April	651120	751440	1402560	April	788880	866400	1655280
May	1212720	1379280	2592000	May	699120	699120	1305600	May	591120	740640	1331760
June	548880	654720	1203600	June	567600	677280	1244880	June	587280	728400	1315680
July	610320	840960	1451280	July	558720	810480	1369200	July	679920	920880	1600800
August	659040	780000	1439040	August	765600	918240	1683840	August	616080	834480	1450560
September	736080	897600	1633680	September	537360	668400	1205760	September	898320	896640	1794960
October	658800	879120	1537920	October	787440	995040	1782480	October	720,000	909840	1629840
November	594000	735360	1329360	November	730560	912000	1642560	November	757680	972000	1729680
December	672000	849840	1521840	December	566880	772560	1339440	December	738,720	993360	1732080
			16950240				17097840				18638880

10.1.2 Electricity Records Continued

	Calendar Year 2002				Calendar Year 2003				Calendar Year 2004		
Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh	Month	Peak	Off Peak	Total kWh
January	584160	782160	1366320	January	579840	850560	1430400	January	551040	809760	1360800
February	698400	964080	1662480	February	657840	812160	1470000	February	621600	766560	1388160
March	848160	990000	1838160	March	606240	713280	1319520	March	738480	858960	1597440
April	782160	860160	1642320	April	637200	738480	1375680	April	891360	966240	1857600
May	414000	515040	929040	May	670560	736800	1407360	May	438000	518880	956880
June	618000	804720	1422720	June	762240	927600	1689840	June	644400	726480	1370880
July	724320	866160	1590480	July	540720	658320	1199040	July	686640	791760	1478400
August	772080	859440	1631520	August	779520	860160	1639680	August	935760	1056480	1992240
September	812400	1058160	1870560	September	373680	569280	942960	Sept	635280	775680	1410960
October	742320	883920	1626240	October	594960	802080	1397040	October	743040	966720	1709760
November	667920	830400	1498320	November	700080	827520	1527600	November	891360	1164000	2055360
December	688800	914640	1603440	December	713040	921120	1634160	December	628560	724560	1353120
Total			18681600				17033280				18531600

10.1.3 Electricity Records Continued

	Calendar Year 2005		
Month	Peak	Off Peak	Total
January	410160	512160	922320
February	633,600	729,600	1363200
March	631200	775200	1406400
April	976800	1094400	2071200
May	360000	456000	816000
June	640800	768000	1408800
July	772800	981600	1754400
August	837600	892800	1730400
September	840000	972000	1812000
October	801600	996000	1797600
November	652800	799200	1452000
December			1450000
Total			17984320