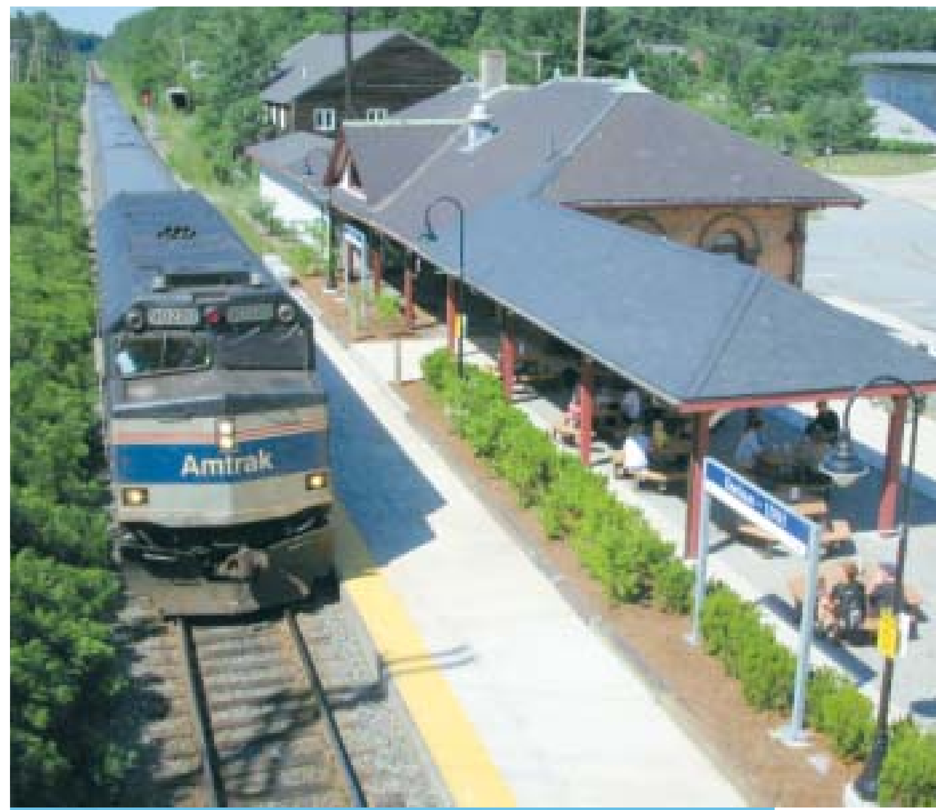
2003

Greenhouse Gas Emissions Inventory 1990-2003 Full Report

UNH Sustainability Institute

University of New Hampshire
Durham Campus

1990-2003
Greenhouse Gas Emissions Inventory



A Collaborative Project By:

UNH Climate Education Initiative
UNH Office of Sustainability Programs
Clean Air – Cool Planet

July 2004

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Cover Photos: AIRMAP monitoring station at Thompson Farm in Durham, NH, Central Heating Plant chimney as seen on campus, energy efficient flourescent light fixture, Amtrak Downester Durham Station on the UNH campus.

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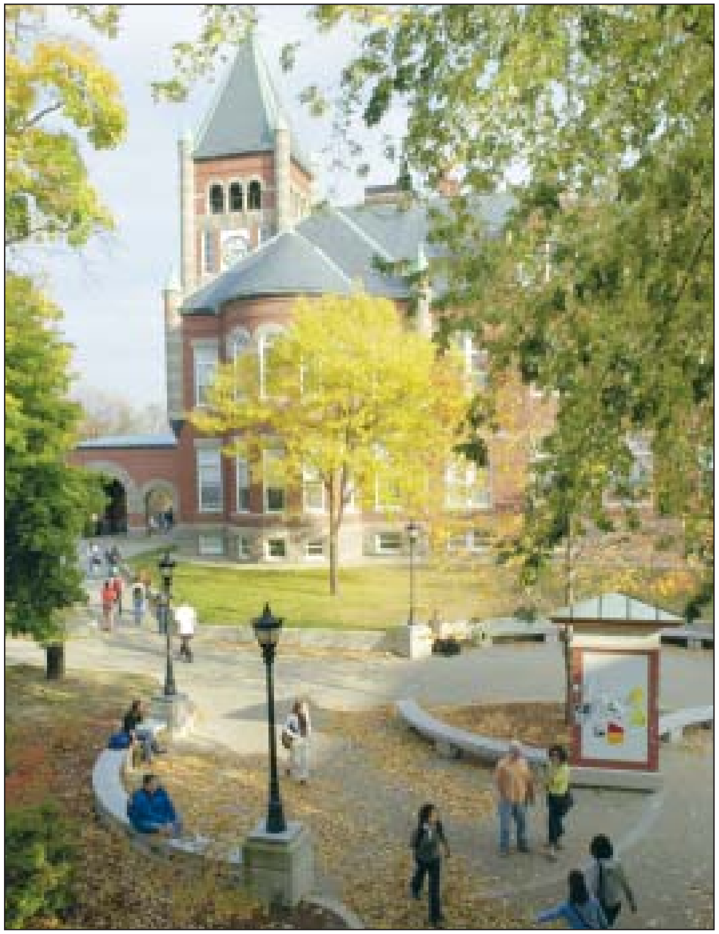


Executive Summary

This report summarizes the findings from an inventory of the anthropogenic greenhouse gas emissions for the University of New Hampshire, Durham campus, from 1990–2003. The purpose of completing the inventory is to clarify the sources of emissions and to guide short- and long-term reduction policies including education and research. The UNH inventory adapts the guidelines of the Intergovernmental Panel on Climate Change (IPCC), a panel of more than 2000 international scientists organized by the World Meteorological Organization and United Nations Environment Programme in 1998, to a university community. The emissions are reported in Metric Tons Carbon Dioxide Equivalents (MTCDE), according to their Global Warming Potential (GWP) to provide the relative contribution of each gas to forcing climate change.

Human activities have led to an enhanced greenhouse effect, commonly referred to as global warming. Since the dawn of the Industrial Age, carbon dioxide concentrations have risen by almost 30%, methane has more than doubled, and nitrous oxide has increased about 15%. In its third assessment report published in 2001, the IPCC concluded, "In light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last fifty years is likely to have been due to the increase in greenhouse gas concentrations." It is certain that human activities have significantly increased concentrations of greenhouse gases in the atmosphere and contributed to the enhanced greenhouse gas effect. While it is unclear exactly what the impacts of a changing climate will be, it is clear that there will be important ecological and therefore human ramifications.

The global average surface temperature has increased over the twentieth century by about 0.6°C. The World Meteorological Organization reported in December 1999 that the 1990s were, globally, the warmest decade since instrumental measurement started in the 1860s. Satellite data shows that there was likely a 10% decrease in snow cover since the late 1960s in the Northern Hemisphere. Northern summer sea-ice extent has decreased by 10-15% and become 40% thinner. Tide gauges have shown that the global average sea level rose 0.1-0.2 meters during the twentieth century. Climate in New England is also changing. Air temperatures in the Northeast United States have increased more than 1°C over the past century, with the greatest warming occurring in southern coastal regions and during the winter season. Precipitation across the region has increased almost 10%, and the growing season length has increased by eight days. Ice out days on lakes are 6-15 days earlier. At Seavy Island, Portsmouth, NH, sea level has risen by almost 0.18 meters (7 inches) in the last century.

With over 15,000 community members, UNH consumes a large amount of energy and therefore is responsible for a significant quantity of greenhouse gas emissions. As a microcosm of society at large, studying UNH's energy use and emissions provides the opportunity to reduce those emissions and educate the university community and the state concerning the significance of energy choices and climate change.

This inventory is an important component in UNH's Climate Education Initiative (CEI). The CEI is a university-wide program integrating the *why* and *how* of greenhouse gas reductions into the teaching, research, operations, and engagement activities of UNH, making it a *climate protection campus*. To achieve its long-term educational goal, the ethics, science, technology, and policies of greenhouse gas reductions must be integrated into the university's community identity and practices. Through this systematic approach, all members of the UNH community are increasing their knowledge and effectiveness in advancing emission reductions in their civic and professional lives.

The explicit goals of the UNH Climate Education Initiative are to:

1) Reduce CO_2 and other greenhouse gas emissions.
2) Educate students and other members of the UNH community about the relationship between human activities and climate change.
3) Strengthen research on impacts, mitigation, and adaptation related to climate change and variability.
4) Develop as a model sustainable community in the state and region.

UNH Emissions - Findings

- UNH emits on average about 60,300 Metric Tons of Carbon Dioxide Equivalents (MTCDE) each year. On average, the yearly percent increase in emissions is 1.8%.
- There has been a net increase (+24.9%) in total emissions from 1990 to 2003 (Figure ES-1).
- When UNH's "upstream emissions" are included in the calculation, the total emissions for the university increase by about 15%. Upstream emissions are the emissions associated with the collection of the source fuel (such as crude oil), and the transport, storage, and refining of the fuels as they are brought to the location of combustion (such as the automobile or university boiler).

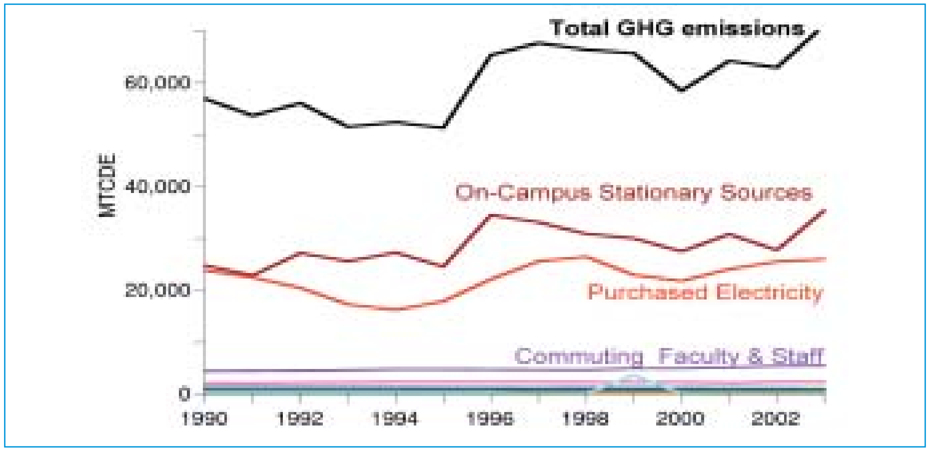


Figure ES-1: Total UNH Direct Emissions 1990-2003
Greenhouse gas (GHG) emission sources and total GHG emissions in metric tons of carbon dioxide equivalents (MTCDE). The lines on the bottom of the graph that are not labeled represent emissions from commuting students (pink), university fleet (blue), agriculture (green), solid waste (brown) and refrigeration (light blue).

Source	1990 MTCDE	2003 MTCDE	% Change
On Campus Stationary Source	24,776	35,366	30
Purchased Electricity	23,827	25,977	8
Transportation: Commuting Faculty/Staff	1,183	1,049	-13
Transportation: Commuting Students	2,097	2,288	8
Transportation: University Fleet	4,408	5,459	19
Agriculture	663	725	9
Solid Waste	N/A	236	N/A

Table ES-1. Percent Change in Emissions per Source for 1990 and 2003. The year 1990 is used as the base year in accordance with international and national protocols. Calculations of solid waste emissions for the years 1990-1996 were not possible because the make-up of waste was not known.

Source	% MTCDE
On-Campus Stationary Sources	49
Purchased Electricity	37
Transportation: Commuting Faculty / Staff	8
Transportation: Commuting Students	3
Transportation: University Fleet	2
Agriculture / Solid Waste	1

Table ES-2: Sources of UNH's Emissions, by percent, for fiscal year 2003. Total greenhouse gas emissions were 71,000 metric tons of carbon dioxide equivalents (MTCDE).

Findings Continued

- The major sources of UNH's emissions result from on-campus stationary sources (49%) and purchased electricity (37%), with all forms of transportation adding up to 13% of total emissions. Solid waste disposal, agriculture and refrigerant releases make up the remaining 1%. (Table ES-2)
- UNH relies predominantly on fossil fuels to meet its energy needs. In fiscal year 2003, the university's energy needs were met by using 81% fossil fuels (coal, oil, gasoline, diesel, natural gas, and propane), 14% nuclear, 5% hydroelectric power production, and 0% renewable. This includes on-campus production, off-campus electricity production, and transportation.
- Total energy use has increased (+33.5%) and energy use per student has also increased (+14.5%) from 1990 to 2003. The increase is due to major new construction projects and significant addition of air conditioning to campus buildings.
- Energy use per square foot has decreased (-5%) from 213 KBtu per SF in 1989 to 204 kBtu per SF in 2003.
- From 1990 to 2003, dependence upon electricity generated by a regional provider has restricted UNH's ability to achieve more aggressive reduction goals.
- Projected emission reductions with a combined heating and power (CHP) facility, approved by the UNH Board of Trustees in February 2004, will exceed internationally established reduction goals (40%) including those called for by the New England Governors and Eastern Canadian Premiers (NEG/ECP) Climate Action Plan (Figure ES-2).
- In order to maintain its "beyond compliance" status resulting from the CHP, UNH will need to continue pursuing aggressive medium and long-term reduction policies.

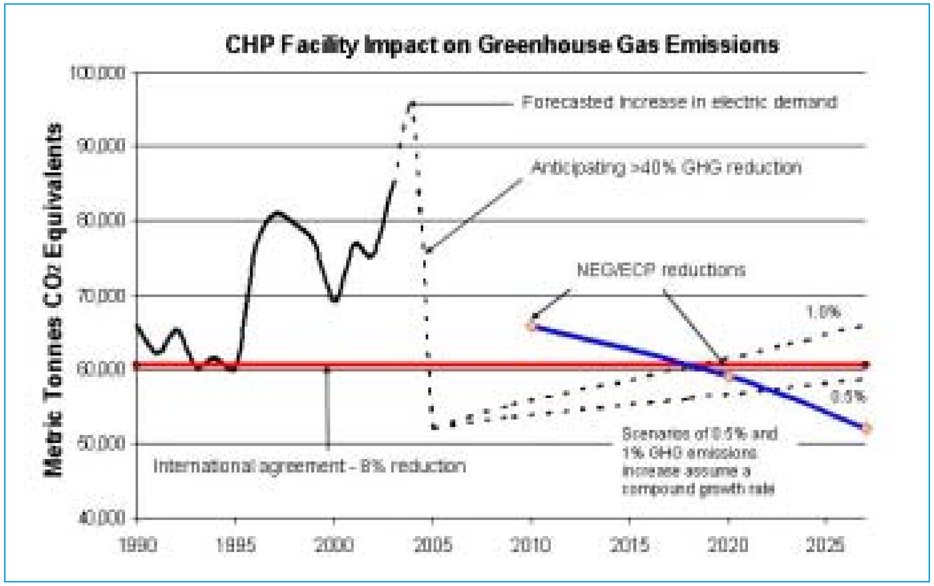


Figure ES-2: Prediction of Impact to UNH's Greenhouse Gas Emissions with a Combined Heating and Power (CHP) Facility. The dotted line represents the drop in emissions when the CHP comes on line in 2005.

Conclusions and Recommendations

General

- **UNH is Making Progress.** UNH has initiated policies that reduce emissions in its campus operations. Despite a growing population of faculty, staff, and students, greenhouse gas emissions have increased at a significantly slower rate than the national average. This was primarily due to a shift from carbon-intensive energy production (such as an incinerator) to natural gas use on campus and energy efficiency projects of the UNH Energy Office. According to a study completed by the US Department of Energy, UNH Energy Office saves $4 million a year (compared to other schools in UNH's peer group in 2000) in reduced consumption due to its efficient use of energy.

- **Energy Consumption Continues to Increase.** Energy consumption and greenhouse gas emissions have increased over the past fourteen years due to infrastructure expansion and added air conditioning. This increase now outpaces efficiency upgrades and behavioral changes resulting from educational efforts.

- **Sustainability Makes Financial Sense.** As a result of rigorous financial and environmental analysis, the UNH Board of Trustees approved the construction of a combined heat and power facility (CHP) slated to come on line in the fall of 2005. Calculations of emissions under the CHP scenario beginning in 2005 project a 40% decrease in the university's greenhouse gas emissions (Figure ES-2). This level of emissions reduction will move UNH well beyond internationally agreed upon reduction targets including those established by the New England Governors and Eastern Canadian Premiers Climate Action Plan. Importantly, these emissions reductions will be achieved with existing technology deployed through a financially-sound business model thereby improving public and environmental health as well economic productivity and competitiveness.

Source-Specific

On-campus Stationary Sources

- **Conclusion:** The production of energy on campus, referred to as "on-campus stationary sources," is the largest producer of emissions, 49% in fiscal year 2003 (Table ES-2). The majority of emissions from on-campus stationary sources occur through the combustion of fossil fuels in the Central Heating Plant to produce steam and hot water.

- **Recommendation:** 1) UNH should maintain its commitment to build the combined heating and power facility (CHP) that will supply the university with energy-efficient heat and electricity. This type of plant uses heat produced in electric generation to heat and cool buildings. This local energy production technology avoids the larger waste heat losses (typically 60%) at large utility power plants. 2) UNH should broaden the reach of educational efforts to further reduce the on-campus stationary source emissions directly through changes in the behavior of UNH's community members.

Purchased Electricity

- **Conclusion:** The production of energy off campus through electric power generation is the second largest contributor of greenhouse gas emissions, 37% in fiscal year 2003 (Table ES-2). UNH purchases its electricity from the New England pool of energy providers and in 2003 purchased 57,844,401 kilowatt hours. Even with the new CHP facility, UNH will still need to purchase 10-20% of its electricity. The fuels used to produce this electricity in New England since the early 1990s have shifted to less carbon intensive fuels (e.g. natural gas, hydroelectric, and nuclear energy). Renewable energy sources account for approximately 0% of the energy market available to UNH.

- **Recommendation:** Despite the anticipated reduction in purchased electricity and the deregulation of the electric market, UNH should factor the educational and social benefits of cleaner power into the decision of what kind of electric production methods to support such as renewable energy sources (biomass, solar, wind, etc.). The CEI Working Group in conjunction with university officials should conduct an analysis of options for green energy procurement available under the recently deregulated energy market and provide recommendations to the UNH administration. Options should include financial analysis of forming or joining a green energy purchasing consortium.

Transportation (Commuting Students, Faculty/ Staff and Transit)

- **Conclusion:** Transportation at UNH is the third largest contributor of greenhouse gas emissions, 13% in fiscal year 2003 (Table ES-2). The emissions result from the daily commuting habits of students, staff, and faculty as well as the operation of UNH's two transit systems. With approximately 2,800 faculty and staff commuting daily, and an additional 4,000 students commuting 3.5 times a week to campus, transportation via single-occupancy vehicles is a community-wide concern. Since adopting a Transportation Demand Management (TDM) policy, policy performance and efficiency has improved through a wide variety of projects undertaken by UNH Transportation Services and Campus Planning. However, full policy implementation has been notably slowed by two factors: 1) faculty contract negotiations nullified a tiered pricing system for campus parking improvements, 2) limited implementation of transportation policies by the Town of Durham called for under its 2002 master plan update.

- **Recommendation:** 1) UNH should continue to incorporate principles of Transportation Demand Management (TDM) into decisions made regarding all forms of transportation and campus development. TDM is a tool to maximize mobility while reducing congestion and the resulting pollution. TDM includes: an efficient transit system, carpooling, parking management strategies, alternative mode incentive programs, bicycles and pedestrian infrastructure enhancements, and housing and scheduling management. 2) The university fleet should continue to replace its diesel-burning fleet with more advanced sustainable technologies such as compressed natural gas, low sulfur–low emission diesel and/or electric/hybrid technologies. Diesel that remains part of the UNH fleet should be biodiesel sourced and regionally produced. 3) An aggressive education campaign to address the "car culture" mentality should occur to emphasize the availability of other choices such as transit, carpooling, and cycling including regional intercity transit and rail travel options. 4) Work with the Town of Durham to fully implement its transportation policies as called for under the town's 2002 master plan update.

Agriculture, Solid Waste, and Refrigerants

- **Conclusion:** This category makes up a small percentage of UNH's emissions, less than 1.5% in fiscal year 2003. The category includes emissions from UNH's dairy, swine, and equine facilities in addition to emissions from solid waste deposited in landfills. In 2002 and 2003, there were no emissions from refrigerants.
- **Recommendation:** Agriculture: UNH should pursue viable opportunities to capture methane from agriculture (dairy, equine, and swine) for energy use. Solid Waste: Continue to pursue integrated waste management to reduce waste streams and improve recycling efficiency.

In 2003, a *Computer Purchase and Disposal Procedure* proposal was presented to the administration that outlined steps for a disposal policy that is both environmentally and fiscally responsible.

Community

UNH Policy

- **Conclusion:** UNH energy policy, including the efficiency projects of the Energy Office, have to date been driven largely by economics and technology. However, two factors point to the importance of placing UNH energy policy in a broader educational context. First, energy demand will likely continue to increase without purposeful policies to mitigate that trend that include an explicit community ethic to conserve energy. Second, with the establishment of the Office of Sustainability Programs in 1997, UNH has committed itself to a university-wide educational goal of ensuring that all of its graduates develop the competence and character to advance sustainability in their civic and professional lives. UNH Policy can only be achieved through modeling energy efficiency and other greenhouse gas reduction policies and integrating those practices into teaching, research, and engagement activities of the university.

- **Recommendation:** 1) UNH should continue aggressive efforts to increase its energy efficiency and reduce its emissions in all areas. 2) UNH should approach energy decisions keeping in mind not only direct financial costs, but also the environmental and educational effects of efficient energy production and consumption. 3) UNH should incorporate sustainability into implementation of all aspects of the recently updated campus master plan including sustainable design and construction principles, projects of the Campus Energy Office, transportation Demand Management and sustainable landscaping.

Education

- **Conclusion:** The educational goals of the Climate Education Initiative can only be achieved by integrating the *why* and *how* of greenhouse gas reductions across the teaching, research, operations and engagement activities of the UNH land grant mission.

- **Recommendation:** 1) UNH should continue its strong commitment to the *climate protection campus* a part of its community identity, and work with the Climate Education Initiative Working Group to track progress towards long-term goals using CEI indicators. 2) UNH should incorporate emission reduction education, expectations, and concrete guidelines into its Freshman orientation activities both online and on-campus.

Report
The UNH Greenhouse Gas Emissions Inventory (1990-2003)

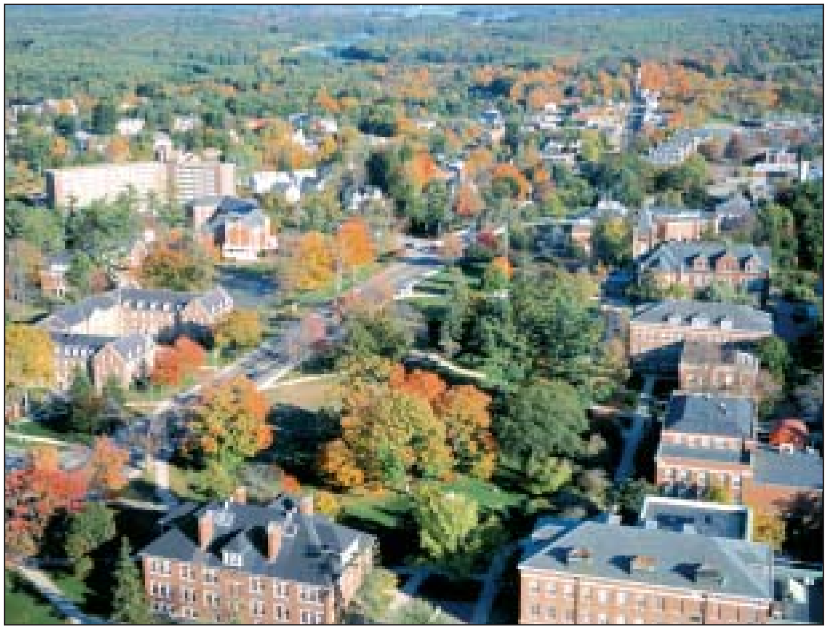
Project Background

In the winter of 2000, the University of New Hampshire Office of Sustainability Programs (OSP) developed a partnership with the Portsmouth, New Hampshire-based non-profit Clean Air-Cool Planet (CA-CP). The partnership was part of the UNH Climate Education Initiative (CEI), a university-wide effort to establish UNH as a ***Climate Protection Campus***. As such, UNH integrates the ethics, science, technology, and policies affiliated with greenhouse gas reductions into its community identity and practices. One of the first collaborative projects was the development of a greenhouse gas inventory tool that adapted national and international inventory methodologies to the unique scale and character of a university community.

Combining financial and intellectual resources, the partners hired a graduate student, Adam Wilson, who developed the inventory tool and gathered data to produce UNH's first greenhouse gas emissions inventory report, *Greenhouse Gas Emissions Inventory 1990-2000*, which was published in May 2001. Following its publication, Adam worked with CA-CP to package the inventory methodology into a generic tool that could be used by other campuses. The Campus Greenhouse Gas Emissions Inventory Calculator became available in the fall of 2001 and, over the next 18 months, was employed by approximately 10 other Northeast campuses. Based on that body of experience, OSP and CA-CP hosted several technical meetings to continue refining and simplifying the calculator leading to the development of a revised version which was first used at UNH in 2003-2004. Parallel to the beta testing of the revised calculator, UNH initiated the gathering of data from 2001-2003 with which to update its original emissions inventory, leading to this publication which represents UNH's emissions profile for the period 1990-2003. Copies of this emissions inventory report can be obtained by contacting the Office of Sustainability Programs at 603.862.4088 or online as a PDF at www.sustainableunh.unh.edu/climate_ed. The Greenhouse Gas Emissions Inventory Calculator is available to other campuses and is distributed by Clean Air – Cool Planet at 603.422.6464.

The *1990-2003 Greenhouse Gas Emissions Inventory* report was published in conjunction with a meeting of university representatives under the auspices of the New England Governors and Eastern Canadian Premiers (NEG/ECP) at the University of New Hampshire in June 2004. The meeting was organized to advance NEG/ECP's Regional Climate Change Action Plan with a particular focus on the region's higher education sector. UNH's 1990-2003 inventory report was presented to participants of the June 2004 meeting as part of the comprehensive CEI vision to integrate climate protection into UNH's teaching, research, operations, and engagement activities. As part of the CEI, UNH's greenhouse gas emissions inventory will be updated on an annual basis.

Special thanks to members of the CEI Working Group who provided assistance in the collection of 2001-2003 data and also review of this report: Jim Dombrosk, Manager, UNH Campus Energy Office; Stacy VanDeveer, UNH Professor of Political Science; Cameron Wake, UNH Associate Research Professor, Climate Change Research Center; Steve Pesci, UNH Campus Planning; Julie Newman, Education Director, UNH Office of Sustainability Programs; and Tom Kelly, Director, UNH Office of Sustainability Programs. In the 2004 update, three UNH students were involved with the behind-the-scenes data collection, Jordan Macy, Gerry Hornok, and Matt Syzmanowicz. Leigh Dunkelberger, Climate Education Initiative Program Coordinator, UNH Office of Sustainability Programs provided overall project management.



The UNH campus blends with the town fabric of Durham on the east with an array of fields, woods, wetlands, ponds and streams on the west. Visible in the distance is the Oyster River that flows to the Great Bay estuary.

Project Partners

UNH Office of Sustainability Programs

The UNH Office of Sustainability Programs (OSP) was established in 1997 to develop a university-wide education program that links the principles of sustainability to community life. OSP initiatives integrate sustainability practices into all facets of UNH's land grant mission including teaching, research, campus operations, and outreach and engagement. All initiatives involve collaboration with faculty, staff, and students as well as local, regional, and international partners. OSP achieves its goals through policy, curriculum, engagement, and research. OSP collaborates with partners that share the common goal of improving community life.

Contact Information:

107 Nesmith Hall, University of New Hampshire, Durham, NH 03824.
603.862.4088 **www.sustainableunh.unh.edu**

The University's buildings, roads and open spaces fit into an intricate, variegated terrain in a way best characterized as a microcosm of the New England townscape." Source – UNH Comprehensive Campus Master Plan 1994

UNH Climate Education Initiative

The UNH Climate Education Initiative (CEI) is a campus-wide initiative coordinated by the UNH Office of Sustainability Programs. The goal of the CEI is to establish UNH as a *climate protection campus* in which students, faculty, staff, and administrators from all colleges increase their knowledge and effectiveness in advancing emission reductions in their civic and professional lives. The CEI is guided by a university-wide working group that initiates and coordinates teaching, research, campus policy, and engagement projects to advance the CEI goals. Major CEI partners in this project were the UNH Energy Office and Climate Change Research Center.

Contact Information:

A listing of the CEI Working Group members is included on the inside back cover. **www.sustainableunh.unh.edu/climate_ed**

Clean Air-Cool Planet

Clean Air-Cool Planet (CA-CP) is an action-oriented advocacy group that seeks to reduce the threat of global warming by engaging organizations and institutions in all sectors of civil society to take actions that lead to rapid cuts that will reduce greenhouse gas emissions. With offices in Portsmouth, NH and New Canaan, CT, CA-CP is active throughout New England, New Jersey and New York. Clean Air-Cool Planet's higher education program is designed to engage administrators, students, faculty, and staff in the regional and global effort to mitigate climate change discourse by increasing awareness about the issue and catalyzing direct action to reduce greenhouse gas emissions from campuses throughout the northeast.

Contact Information:

Ned Raynolds, Senior Program Officer, 100 Market Street, Suite 204, Portsmouth, NH 03801 603.422.6464 **www.cleanair-coolplanet.org**

Introduction

This report summarizes the anthropogenic greenhouse gas emissions for the University of New Hampshire from 1990 to 2003. The emissions are presented in both weight of the gases emitted and in Metric Tons Carbon Dioxide Equivalents (MTCDE), according to their Global Warming Potential (GWP) to provide the relative contribution of each gas to climate change[1]. The inventory follows the guidelines of the Intergovernmental Panel on Climate Change (IPCC) that were adapted for use at a University[2]. The purpose of completing an inventory of anthropogenic greenhouse gas emissions is twofold: first, to better understand the sources of emissions and second, to investigate the possibility of reducing them.

What is "Climate Change"?

Climate change refers to "fluctuations in the temperature, precipitation, wind, and other elements of Earth's climate system[3]." These fluctuations can be influenced by a variety of natural factors including changes in orbital parameters, volcanic activity, and solar irradiance. Climate change can also be brought about with a change in the composition of the atmosphere. The planet is kept at a hospitable average temperature of 15.5°C (60° F) due to the insulating layer of greenhouse gases that encapsulate the surface[4]. These gases, (which include water vapor, the most significant greenhouse gas), absorb some of the sun's energy and keep the enclosed surface warm. This phenomenon, known as the greenhouse effect, is a necessary component of the many systems needed to support life on Earth.

However, human activities have led to an "enhanced greenhouse effect," also known as global warming. Since the dawn of the Industrial Age, carbon dioxide concentrations have risen almost 30%, methane has more than doubled, and nitrous oxide has increased about 15%. The IPCC has reported, "the balance of evidence suggests a discernible human influence on global climate." [5] It is certain that human activities have significantly increased the amount of gases in the atmosphere that contribute to this effect. While it is unclear exactly what the impacts of a rapidly warming planet will be, it is clear that there will be significant changes. There are many gases that contribute to the greenhouse effect, some directly and others indirectly. The most important of these gases have been identified by IPCC, and focused upon by the international community as the emissions that should be reduced to curb the "enhanced greenhouse effect."

Fossil-fuel burning power plant located on the banks of the Piscataqua River in Portsmouth, NH only 12 minutes from the UNH Durham campus.

These storage tanks, located next to the UNH Central Heating Plant hold the number 6 fuel oil that is burned inside the plant to produce steam and hot water.

Primary Greenhouse Gases

Carbon Dioxide (CO_2) – Carbon is a continually cycling element that moves between the atmosphere, ocean, land biota, marine biota, and mineral reserves. In the atmosphere, carbon exists primarily as carbon dioxide, which is a part of global biogeochemical cycling. The atmospheric concentration of CO_2 has increased by 31% since 1750 and has likely not been exceeded during the past 20 million years. About three quarters of anthropogenic CO_2 emissions are from burning fossil fuels, the other quarter from land-use changes, primarily deforestation (Figure 1)[6].

Methane (CH_4) – Methane is produced primarily through anaerobic decomposition of organic matter in living systems. It is produced in the stomachs of cows and pigs and from their manure, as well as from rice paddies and landfills. It is also released with the collection, processing, and combustion of fossil fuels. The atmospheric concentration of CH_4 has increased 151% since 1750 and continues to increase. The present concentration has not been exceeded during the past 420,000 years (Figure 1)[6].

CO_2 Emissions from Biogenic Sources

The U.S. and all other parties to the Framework Convention on Climate Change agreed to develop inventories of greenhouse gas emissions (GHG) for purposes of: 1) developing mitigation strategies, and 2) monitoring the progress of those strategies. The Intergovernmental Panel on Climate Change (IPCC) developed a set of inventory methods to be used as the international standard. One of the elements of the IPCC guidance that deserves special mention is the approach used to address CO_2 emissions from biogenic sources. In the earth's carbon cycle, CO_2 is removed from the atmosphere through natural processes such as photosynthesis and converted to carbon. This carbon is stored in items such as wood, paper and grass trimmings and eventually cycles back to the atmosphere as CO_2 through degradation processes. The quantity of carbon that these natural processes cycle through the earth's atmosphere, waters, soils, and biota is much greater than the quantity added by anthropogenic GHG sources. However, the focus of the Framework Convention on Climate Change is on anthropogenic emissions; those emissions resulting from human activities and subject to human control. It is these emissions that have the potential to alter the climate by disrupting the natural balances in carbon's biogeochemical cycle, and altering the atmosphere's heat-trapping ability. Thus, for processes with CO_2 emissions, if (a) the emissions are from biogenic materials, and (b) the materials are grown on a sustainable basis, then those emissions are considered to simply close the loop in the natural carbon cycle. In this case, the CO_2 emissions from wood and biomass are not counted. On the other hand, CO_2 emissions from burning fossil fuels are counted because these emissions would not enter the cycle were it not for human activity. Likewise, methane (CH_4) emissions would not be emitted were it not for the human activity of landfilling the waste, which creates anaerobic conditions (i.e. without oxygen) conducive to methane formation.

Source: Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, US EPA, 1998 www.epa.gov/epaoswer/non-hw/muncpl/ghg/greengas.pdf

Nitrous Oxide (N_2O) – Nitrous Oxide is also produced with the combustion of fossil fuels, as well as in agriculture and some industrial processes. N_2O concentrations have increased 17% since 1750 (Figure 1)[6]. The high atmospheric lifetime of N_2O and its global warming potential makes N_2O the second most important greenhouse gas next to CO_2.

Others: Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexaflouride (HFC, PFC, SF_6) – Halocarbons are primarily produced for industrial processes. HFCs were introduced as replacements for ozone-depleting substances, primarily as refrigerants. HFCs and SF_6 are used in aluminum smelting, electric power distribution, and magnesium casting. These chemicals are powerful greenhouse gases and have very long atmospheric lifetimes. The atmospheric concentration of these gases is increasing (Figure 1)[6].

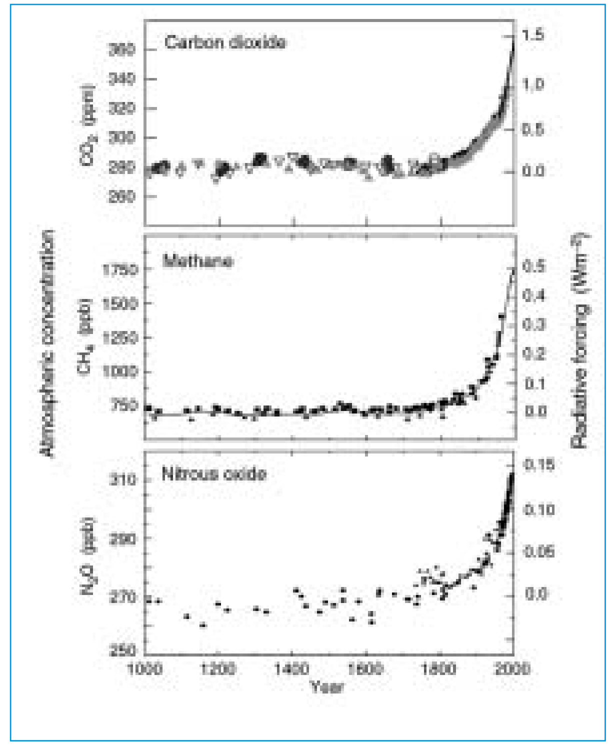


Figure 1: Atmospheric Composition from 1000 to 2000 A.D. Long records of past changes in atmospheric composition provide the context for the influence of anthropogenic emissions. These graphs show changes in the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) over the past 1,000 years. The ice core data for several sites in Antarctica and Greenland (shown by different symbols) are supplemented with the data from direct atmospheric samples over the past few decades (shown by the line for CO_2 and incorporated in the curve representing the global average of CH_4). The estimated positive radiative forcing of the climate system from these gases is indicated on the right-hand scale. Since these gases have atmospheric lifetimes of a decade or more, they are well mixed, and their concentrations reflect emissions from sources throughout the globe. All three records show effects of the large and increasing growth in anthropogenic emissions during the Industrial Era. Source: *Summary for Policymakers, A Report of Working Group I of the Intergovernmental Panel on Climate Change*, 2001.

How do you measure Greenhouse Gases?

Each greenhouse gas traps the sun's energy to varying degrees. This is called the chemical's radiative forcing (or global warming potential– [GWP]). By measuring and describing a greenhouse gas in terms of its global warming potential, its radiative forcing can be converted to a similar unit of carbon dioxide equivalents. The radiative forcing of a gas is dependent on how it reacts with long-wave radiation coming from the Earth and how long lived it is (Table 1). For example, one molecule of SF_6 warms the planet to a similar extent as 23,900 molecules of CO_2. The emissions in this report are reported in Metric Tons Carbon Dioxide Equivalents (MTCDE). This value is the product of the weight of the gas in metric tons and the GWP (For example, 1 metric ton of CH_4 is 21 MTCDE). This unit allows for a quick comparison of different gases relative to the effect they have in the atmosphere.

Gas	Atmospheric Lifetime (Years)	Global Warming Potential (100 Year)
Carbon Dioxide (CO_2)	50-200	1
Methane (CH_4)	9-15	21
Nitrous Oxide (N_2O)	120	310
HFC – 134A	15	1,300
HFC – 404A[8]	>48	3,260
Sulfur Hexafluoride (SF_6)	3,200	23,900

Table 1: Global Warming Potentials and Atmospheric Lifetime of several greenhouse gases[7]

Observed Indicators of Climatic Change

For the past few decades, scientists have been seeking to understand the complex systems that influence our climate. By employing several avenues of study, from ancient ice core and tree ring analysis to historical records and present day recording, it is clear that climate is changing. The global average surface temperature as increased over the twentieth century by about 0.6°C as indicated by the 2001 Report of the *Working Group I of the Intergovermental Panel on Climate Change (IPCC)*. It is very likely that the 1990s was the warmest decade and 1998 the warmest year in instrumental history, since 1861. Satellite data shows that there was likely a 10% decrease in snowcover since the late 1960s in the Northern Hemisphere. Northern summer sea-ice extent has decreased by 10-15% and become 40% thinner. Tide gauges have shown that the global average sea level rose 0.1-0.2 meters during the twentieth century .

Averaged across the Northeast region of the United States, air temperatures have increased more than 1°C over the past century, with the greatest warming occurring in southern coastal regions and during the winter season. Precipitation across the region has increased almost 10%, and the growing season length has increased by eight days. Ice out days on lakes are on average 6-15 days earlier. At Seavy Island/ Portsmouth, NH, sea level has risen by almost 0.18 meters (7 inches) a century[10].

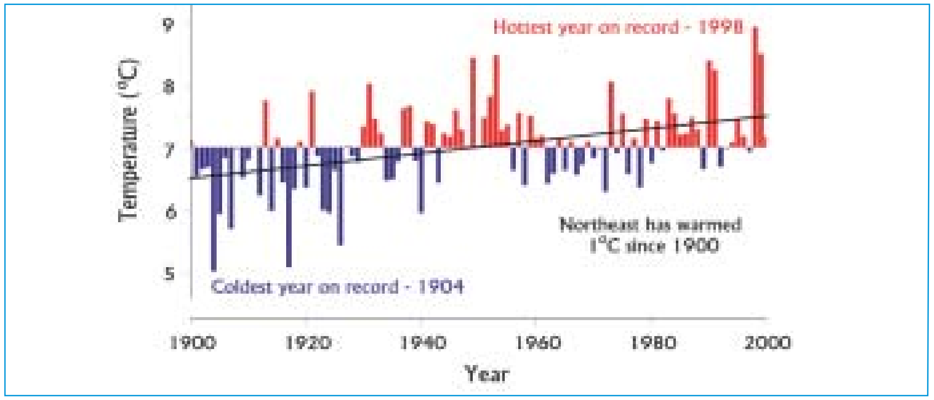


Figure 2: Average annual temperature in the Northeast, 1899-2000. Time-series represents an annually weighted average of data from 56 stations in the Northeast that have been in operation continuously since 1900. Data from the NOAA-National Climatic Data Center (ftp://ftp.ncdc.noaa.gov/pub/data/ushcn).

Predictions of Climatic Change

Greenhouse gas emissions today will continue to alter atmospheric composition and influence climate through the twenty-first century. Projections from several different climate models indicate that global average temperature will increase between 1.4 and 5.8°C between 1990 and 2100[11]. Sea level is projected to rise by 0.09 to 0.88 meters between 1990 and 2100. In New Hampshire, temperatures could increase by as much as 5.5°C. Sea level rise in Portsmouth, NH, could increase by another 0.45 meters (18 inches) by 2100[12] .

Climate Change Impacts

Many of the planet's ecosystems, including human systems, are vulnerable to climate change. Even the slightest changes to temperature and sea level could have major consequences. Globally, we are likely to see increases in frequency and severity of droughts, floods, fires, heat waves, avalanches, hurricanes and windstorms. These events are likely to increase incidence of death and serious illnesses in older age groups and urban poor, infectious disease epidemics, heat stress of livestock, flood and landslide damage, and forest fires. There will also likely be decreased crop yields and available water for irrigation and other agricultural purposes[13].

Along with the increase in temperature and sea level, there are a host of other indirect effects of climate change that may impact New Hampshire. Southern New Hampshire already exceeds national ozone pollution health standards, and a warming climate could increase ozone levels in urban areas. Disease carrying insects, such as Lyme disease-carrying ticks, could become more common as their habitat expands northward with warmer weather. Adapting to a 0.5 meter (20 inch) increase in sea-level rise in Portsmouth would likely cost hundreds of millions of dollars. A changing climate could also affect ecosystem health and even lead to shifts in ecosystem types. For example, a warmer climate could result in the loss of sugar maples throughout southern New Hampshire and Vermont, and with it the loss of our maple sugar industry. The salt marshes near the University of New Hampshire could also be adversely affected by changes in runoff and sea level.[12]

Conducting a Greenhouse Gas Emissions Inventory

The University of New Hampshire, founded in 1866, is a rural campus with about 12,000 students and 2,500 faculty and staff. The campus occupies over 1,000 acres of woods, fields, and developed areas. About half of the student body lives on campus, and few faculty staff or students live farther than 25 miles away. With over 15,000 community members, UNH consumes a large amount of energy and therefore is responsible for a significant quantity of greenhouse gas emissions. As a microcosm of society at large, studying UNH's energy use and emissions provides the opportunity to reduce those emissions and educate the university community and the state concerning the significance of energy choices and climate change.

Inventory Methods

The methods used to calculate UNH's greenhouse gas emissions were adapted from the guidelines provided by the Intergovernmental Panel on Climate Change (IPCC). The IPCC created spreadsheets designed for conducting a nationwide greenhouse gas emissions inventory and provides spreadsheets to assist with the calculations[14]. This report is based on spreadsheets adapted directly from the IPCC spreadsheets (with some sections drawn from the US Inventory and the New Hampshire Inventory as noted). A full set of the spreadsheets used and their explanations are included in the Appendix.

For reporting purposes, the university's emissions sources are divided into four categories: energy, waste, agriculture, and refrigeration. The energy section includes the emissions from purchased electricity (from off campus electric providers), on-campus stationary sources (heating and cooking), and transportation (commuters and university transit/fleet vehicles). The emission estimates in the energy section are based on regional and national average emission factors for the quantities of the various fuels burned. The waste section includes solid and liquid waste disposal and decomposition. The agriculture section includes animal management (enteric fermentation and manure management) but does not estimate soil management emissions, as they are insignificant. The refrigeration section includes all released HFC and PFC refrigerants. The UN Framework Convention on Climate Change and the IPCC both use 1990 as the base year. In this report, we have made comparisons to this year as well.

Data collection is an important component of the inventory. Approximately 10 different UNH departments submitted information for the inventory. Since each department has a unique collection and reporting system, overall data collection required several site visits and follow-up phone calls. In several instances, data was not available for certain years and approximation techniques were used.

There are several sources of emissions that were not included in this inventory, most notably the production of materials consumed by UNH. This inventory makes no estimates regarding paper use, food production, or construction materials. While it would be beneficial to complete such an inventory, its complexity is beyond the scope of this project. In addition, this inventory does not estimate the emissions from university community members' off-campus activities (with the exception of their commuter habits of transportation to and from the university). For example, the energy consumption of student or faculty off-campus homes is not included. There is no reliable way to estimate these emissions and even if there were, a boundary must be drawn somewhere or there would be no limit to the emissions associated with the university. Instead, this inventory was focused on the sources of emissions that the university has some direct influence upon. UNH has direct control of the type of fuels it uses to produce heat and the energy efficiency of building design. It also has control of how much electricity it uses and will soon have control of how that electricity is produced. UNH can also exercise influence on commuter habits by offering alternatives to the personal automobile, a significant source of UNH's emissions. While not completely exhaustive, this inventory can serve as a more-than adequate foundation for assisting in the development of UNH energy policy.

Inventory Findings

Total Direct Emissions

Over the past 13 years, the University of New Hampshire has emitted an average of 60,300 MTCDE annually (Figure 3, Table 2 in Appendix). The average annual increase in greenhouse gas emissions of 1.8% is substantially less than the national average of 3%. The majority of UNH emissions are from on-campus stationary sources (49%) and electricity (37%), with all forms of transportation adding up to 13% of total emissions. Solid waste disposal, agriculture, and refrigerant releases make up the remaining 1.5%. Emissions trends can be defined by three major periods:

- From 1990 to 1995, there was a net decrease in emissions (-9.9%) that can be accounted for by slow campus growth and energy saving measures installed by the UNH Energy Office.
- From 1995 to 1999, there was a net increase in emissions (+28.2%) that was due to the addition of five new campus buildings (Whittemore Center, Environmental Technology Building, Chase Oceanography Building, Rudman Hall, and the Memorial Union Building expansion). In addition, 1996 was the first year that residence halls were wired for Internet access and cable television, which is likely responsible for some of the increase in the use of electricity. The winter of 1995 was especially mild, so the emissions are the lowest for that year[15].
- From 1999 to 2003, there was a net increase in emissions (+8.2%). This growth is smaller as compared to the 1995-1999 years and is due to continuing construction (Mills Hall, Holloway Commons) and increase in air conditioning which was added to many buildings (Murkland, Congreve, Hewitt, Pettee, Mills, and the MUB addition)[15].

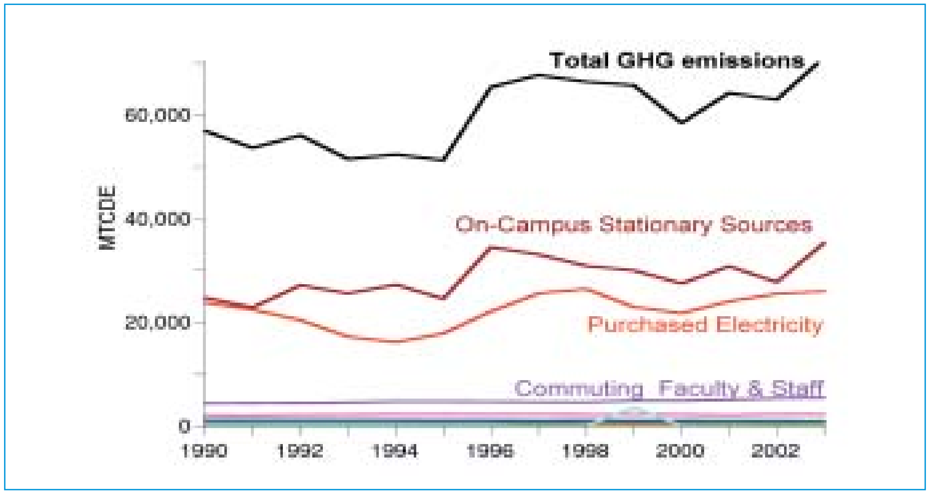


Figure 3: Total UNH Direct Emissions 1990 -2003
Greenhouse gas (GHG) emission sources and total GHG emissions in metric tons of carbon dioxide equivalents (MTCDE). The lines on the bottom of the graph that are not labeled represent emissions from commuting students (pink), university fleet (blue), agriculture (green), solid waste (brown) and refrigeration (light blue). The increase of refrigeration emissions for 1998 to 2000 is a result of accidental mechanical failure.

Source	1990 MTCDE	2003 MTCDE	% Change
On Campus Stationary Source	24,776	35,366	30
Purchased Electricity	23,827	25,977	8
Transportation: Commuting Faculty/Staff	1,183	1,049	-13
Transportation: Commuting Students	2,097	2,288	8
Transportation: University Fleet	4,408	5,459	19
Agriculture	663	725	9
Solid Waste	N/A	236	N/A

Table 3A. Percent Change in Direct Emissions per Source for 1990 and 2003. The year 1990 is used as the base year in accordance with international and national protocols. Calculations of solid waste emissions for the years 1990 to 1996 were not possible because the make-up of waste incinerated was not known.

Total Direct and Upstream Emissions

A commonly overlooked source of emissions in greenhouse gas inventories is the "upstream emissions". In this inventory the upstream emissions of consumed fossil fuels are estimated (Figure 4, Table 3 in Appendix). Upstream emissions are the emissions associated with the collection of the source fuel (such as crude oil), and the transport, storage, and refining of the fuels as they are brought to the location of combustion (such as the automobile or university boiler). For example, it takes fuel to power an oil barge across the ocean or drive a tanker truck to deliver gasoline. These emissions are estimated in the U.S. Department of Energy Report, *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation*[16]. However, to meet the guidelines of the IPCC and US EPA, UNH's emissions have been reported both with and without the upstream emissions. When upstream emissions are included, UNH's total emissions (MTCDE) increase by 15%.

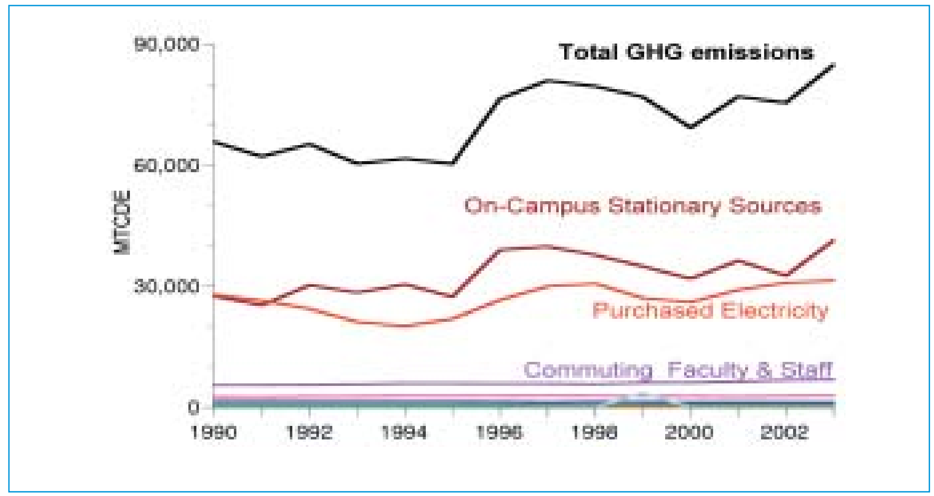


Figure 4: Total UNH Direct and Upstream Emissions 1990 -2003
Greenhouse gas (GHG) emission sources and total GHG emissions in metric tons of carbon dioxide equivalents (MTCDE). The lines on the bottom of the graph that are not labeled represent emissions from commuting students (pink), university fleet (blue), agriculture (green), solid waste (brown) and refrigeration (light blue). The increase of refrigeration emissions for 1998 to 2000 is a result of accidental mechanical failures.

Source	1990 MTCDE	2003 MTCDE	% Change
On Campus Stationary Source	27,525	41,417	34
Purchased Electricity	27,937	31,468	11
Transportation: Commuting Faculty/Staff	5,545	6,866	19
Transportation: Commuting Students	2,637	2,878	8
Transportation: University Fleet	1,477	1,305	-13
Agriculture	658	725	9
Solid Waste	N/A	236	N/A

Table 4A. Percent Change in Direct and Upstream Emissions per Source for 1990 and 2003. The year 1990 is used as the base year in accordance with international and national protocols. Calculations of solid waste emissions for the years 1990-1996 were not possible because the make-up of waste was not known.

Trends in UNH Emissions

Total emissions from the years 1990 to 2000 can be misleading. Given the nearly 15% increase in purchased electricity with on-campus energy production increasing roughly 3.5%, one would assume an increasing trend in emissions. However, this was not observed, as emissions remained relatively constant. The primary reasons UNH's emissions did not increase were due to the changing fuel types in electricity production on and off campus. Purchased electricity production shifted from more carbon-rich fuels (coal and heavy oil) to less carbon rich fuels (natural gas, nuclear, and hydroelectric). During this decade, on-campus energy sources also shifted away from incinerator production and fuel oils to more efficient natural gas. Thus a shift to more efficient means of electricity production by both UNH and the regional power provider masked an increase in energy use with relatively steady greenhouse gas emissions.

When considering the recent trend (2001-2003), we see growth in emissions. Due to constraints on reporting of electricity production from the regional provider, a steady fuel mix was assumed for years 2001-2003. The above average emissions for these years are explained by increasing consumption of power generated both off and on-campus leading to a net increase in total campus energy consumption. Contrary to the previous decade when substitution of more efficient fuels masked increasing consumption when considering emissions, growing consumption in the period 2001-2003 translated directly into emission increases. Close monitoring of this trend through the annual update of the emissions inventory will help to validate whether this rise will continue into the future.

When upstream emissions are included with UNH's direct emissions, there is an increase of almost 15% (Figure 4, Table 3 in Appendix). Some fuels, primarily gasoline, which is a highly refined fuel, have relatively higher upstream emissions that are visible in the comparison between the direct and upstream figures (Figures 3, 4).

In addition to the total emissions from the university, emissions and energy use per student were also calculated (Table 4). This measure provides a method to compare institutions of different sizes and types of infrastructure. There was a net increase (9.1%) in emissions per student, most attributable to changes in electricity production and university fuel use (Table 4). Carbon dioxide emitted per student per year is approximately five thousand kilograms (11,000 pounds). There has been a net increase in overall university energy use (22.8%) and in energy use per student (12.6%) with some wide fluctuations (Table 4). As discussed earlier the rise in energy use in 1996 is due at least partly to several new buildings coming online. The dip in 1995 is primarily due to an unusually warm winter.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
UNH Electric Use (MWh)	43.344	43.000	43.518	44.105	43.767	45.033	51.098	50.875	48.903	49.859	50.462	53.591	56.868	57.844
Electric Emissions (kg CDE/kWh)	0.485	0.463	0.414	0.364	0.325	0.349	0.382	0.444	0.478	0.440	0.405	0.449	0.449	0.449
Total MTCDE Emissions	56,950	53,702	56,086	51,525	52,378	51,314	65,399	67,702	66,394	65,769	58,468	64,287	63,019	71,100
% Change from Previous Year		-5.7%	4.4%	-8.1%	1.7%	-2.0%	27.4%	3.5%	-1.9%	-0.9%	-11.1%	10.0%	-2.0%	12.9%
Students	11,566	11,468	11,874	12,257	12,397	12,518	12,414	12,454	12,209	11,857	11,965	12,003	12,624	13,129
MTCDE / Student	4.924	4.683	4.723	4.204	4.225	4.099	5.268	5.436	5.438	5.547	4.887	5.336	4.973	5.419
Total Energy Use (TJ)	965	936	991	988	999	973	1,143	1,161	1,120	1,055	1,031	1,041	1,137	1,250
Energy use / Student (TJ / Student)	0.083	0.082	0.083	0.081	0.081	0.078	0.092	0.093	0.092	0.089	0.097	0.095	0.090	0.095

Table 4: UNH Energy Use and Emission Intensities

Inventory Findings

Emissions by Type of Gas

Of the six greenhouse gases identified in this inventory, carbon dioxide is emitted in the largest amounts by far at UNH. Although the other gases have higher global warming potentials that range from 21 times as powerful as CO_2 in the case of methane, to 23,900 times as powerful in the case of sulfur hexafluoride, CO_2 still has the most effect on the atmosphere of all UNH emissions. In fiscal year 2003, the contribution of emissions by each type of gas is demonstrated in Table 5.

Gas	MTCDE
Carbon Dioxide (CO_2)	69,700
Methane (CH_4)	108
Nitrous Oxide (N_2O)	440
PFC	0
HFC	0
Sulfur Hexafluoride (SF_6)	0

Table 5: Metric tons of carbon dioxide equivalents (MTCDE) Emissions by type of Gas for Fiscal Year 2003

Emissions by Source

With the exception of the elimination of the incinerator as a source of heat (in 1996) and growing use of natural gas, there have been few changes in fuel use on the UNH campus. The use of less carbon-intense fuels for production of electricity has also increased slightly. Fiscal year 2003 (July 1, 2002 – June 30, 2003) provides a representative look at what makes up each of the four sections of the inventory: energy, waste, agriculture, and refrigeration. Each of these sectors is divided up into smaller categories to provide an in-depth look at the sources of UNH's emissions (Table 6 in Appendix).

Source	% MTCDE
On-Campus Stationary Sources	49
Purchased Electricity	37
Transportation: Commuting Faculty / Staff	8
Transportation: Commuting Students	3
Transportation: University Fleet	2
Agriculture/ Solid Waste	1

Table 6: Sources of UNH's Emissions, by percent, for Fiscal Year 2003
Total emissions 71,100 metric tons of carbon dioxide equivalents (MTCDE)

Emissions by Category

This section is organized by emission categories. The categories are energy, waste, agriculture and refrigeration. Each of these sectors can be divided into smaller categories. They include the following:

Energy:
- On Campus Stationary Sources
- Electricity (produced off-campus)
- Transportation - University Fleet
- Transportation - University Community Commuters

Waste:
- Solid Waste Disposal
- Wastewater Treatment

Agriculture:
- Animals
- Soil Management

Refrigeration:
- Refrigerants and Other Chemicals

Energy at UNH

When we discuss energy, we are talking about the conversion of a fuel to heat. At UNH, we need energy to produce electricity for lighting (purchased) and the steam and hot water to heat our buildings (produced on campus). We also need energy for our cars and buses (currently we rely on fossil fuels such as gasoline and diesel from the pump). Since the dawn of the Industrial Age humans have taken advantage of the immense pools of stored energy available as fossil fuels beneath the Earth's crust. Within our political economy this source of energy has been subsidized to make it relatively inexpensive and abundant. However, its use has not been benign and many costs and impacts have been externalized to be addressed politically and financially as environmental and health costs. In addition to numerous air pollutants such as lead and carbon monoxide, fossil fuels are the greatest source of human-induced greenhouse gases in this country[17]. At UNH, 81% of the energy consumed is produced with fossil fuels (Table 7).

Combustion of fossil fuels releases relatively small amounts of methane and nitrous oxide and large amounts of carbon dioxide. Carbon dioxide is released when the carbon present in the fossil fuel is atomized and combines with oxygen to form carbon dioxide, water, and carbon monoxide. Thus the mass of carbon dioxide created is greater than the amount of carbon burned. For example, the combustion of one gallon of gasoline, which has a mass of 2.8 kg (6.3 lbs.), releases 8.4 kg (18.5 lbs.) of carbon dioxide[18]. Furthermore, the carbon content of fuels varies greatly (Table 8 in Appendix). For example, the incinerator released nearly twice as much carbon as natural gas. Emissions are therefore dependent on the type of fuel and the efficiency of combustion.

UNH's Energy Sources	% Percent
Fossil	81
Nuclear	14
Hydro	5
Renewable	0

Table 7: UNH's Energy sources, fiscal year 2003
Data for Table 7 includes on-campus emissions, sources of UNH's electricity, and commuter traffic. "Hydro" refers to hydroelectric power production in the US and Canada. "Fossil" includes fuel oil, gasoline, diesel, propane, natural gas, and coal.

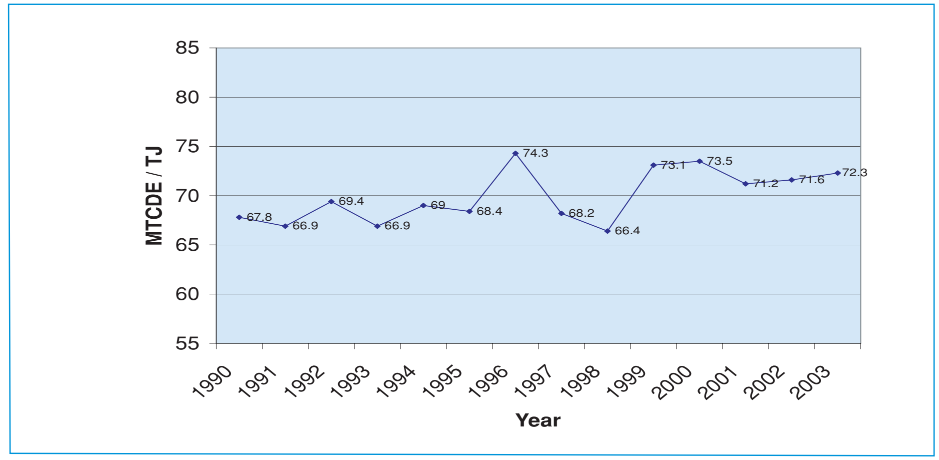


Figure 5: Metric tons of carbon dioxide equivalents (MTCDE) Emissions per Terra Joule (TJ) On-campus Energy Production

Part I: Emissions from the Production of Energy

Emissions from the production of energy at UNH has been divided into four categories: On-campus stationary sources, Electricity production off-campus, University fleet fuel consumption, and University commuter fuel consumption.

On-Campus Stationary Sources

The university utilizes several fuels that are used primarily to generate heat. Number 6 fuel oil and natural gas are burned at the Central Heating Plant to produce steam and hot water. The steam and hot water are then distributed throughout the core campus to heat buildings and provide domestic hot water at sinks and showers. Using absorption technology, UNH uses steam to provide summer air conditioning at Rudman Hall. Number 2 fuel oil is burned at outlying buildings that are not connected to the central heating system, such as the Gables. Number 2 oil is more expensive than number 6 oil, but it is cleaner burning and more suited to smaller furnaces and boilers. Propane and natural gas, which are cleaner burning than oil, are used for cooking, domestic hot water, clothes dryers, and laboratory experiments. Philbrook Dining Hall, Ocean Engineering, and the Printing and Mail Services Building are heated with natural gas.[19]

The UNH Energy Office has been working on more than 30 energy efficiency projects in the past decade that have helped keep emissions relatively steady despite increasing demand. These projects include lighting retrofits, heating controls, and replacement of outdated equipment, as well as a transition to cleaner burning fuels. The incinerator was phased out in 1996 while natural gas was used for the first time. As a result of these recent projects, over 4,500 metric tons of carbon dioxide emissions, which would have been about 7% of total emissions, are avoided annually[19]. These projects also saved the university an estimated $4 million in academic year 2000-2001 from decreased energy consumption[20]. Oak Ridge National Laboratory recently identified UNH's Building Automation System controls, and the ways that they are aggressively used, as the primary reason for our high energy efficiency. In addition, due to these projects emissions per energy unit from 1990 to 1995 was relatively stable, though this figure has recently increased since 1998 (Figure 5).

Natural gas and number 6 fuel oil are burned in furnaces at UNH's Central Heating Plant to create steam for heating buildings and hot water for sinks and showers. There are five furnaces in the plant, two using oil, and three that are dual fuel.

Electricity

UNH uses electricity for air conditioning, office equipment, lights, elevators, etc. Electricity is also used to heat five dormitories, Williamson, Christensen, Hubbard, Babcock, and Stoke Halls. UNH purchases electricity from the Public Service of New Hampshire (PSNH)[21]. The sources of UNH's electricity for each year were gathered from the Independent Service Operators of New England (ISO-NE) annual reports. ISO-NE coordinates the 330 generating facilities in New England[22]. The emissions associated with the production of the electricity consumed were calculated by estimating the amount of each fuel type used to produce the electricity. This estimation includes the efficiency of electricity production for each source within currently employed conversion technology, which is only about 35% (meaning about two-thirds of energy created is wasted in electricity production). The emissions from the production of electricity were included in the inventory even though they were produced off campus because UNH purchased the electricity and is therefore responsible for the emissions. UNH produces small amounts of electricity, but since it is produced with the #6 fuel oil and natural gas, and was accounted for in the On-Campus Stationary Sources section, it will not be included here. UNH also produces small amounts of electricity with solar panels mounted on the roof of the Memorial Union Building.

There have been significant shifts in the type of energy being used to produce the electricity UNH purchases. Due to differing amounts of carbon in each fuel, these variations result in shifts in emissions per kilowatt-hour (Figure 6).

The UNH Energy Office has installed more than 30 energy efficiency projects that include lighting retrofits, heating controls, and replacement of outdated equipment. Energy efficient light fixtures (above), large windows, and glass office doors, were installed in the Nesmith Hall renovation, the home of the Office of Sustainability Programs.

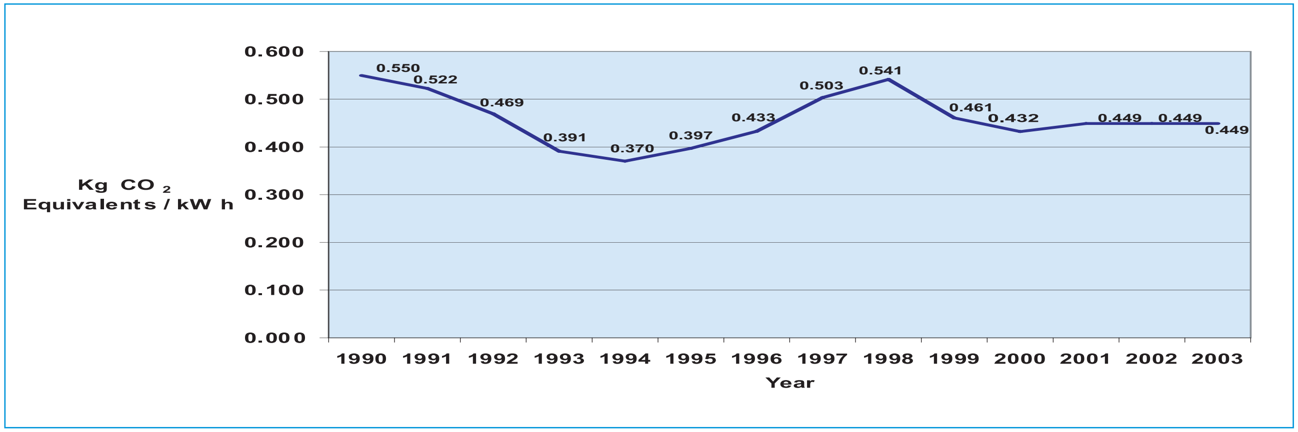


Figure 6: Kg CO_2 Equivalent Emissions per Kilowatt-hour of Electricity. The dip from 1992 to 1995 is due to a temporary increase in nuclear production, while the overall decrease is from a shift to more hydroelectric, natural gas, and biomass production.

Emissions from the Production of Energy continued

University Fleet

The university is the largest single, non-military employer and fleet operator in the seacoast region. UNH owns and maintains about 270 vehicles, all but a handful of which burn gasoline or diesel fuel[24]. These vehicles, including 35 heavy-duty passenger buses, shuttles, maintenance, and departmental vehicles are fueled at the State of NH-owned fueling station located near West Edge parking lot. These vehicles range in year of production from 1984 through the present. Most (<10) use a fuel other than gasoline or diesel fuel. In Spring 2004, UNH expanded its compressed natural gas (CNG) fleet to 14 vehicles with the purchase of six new CNG transit vehicles.

UNH operates two transit systems, Wildcat Transit and Campus Connector. Wildcat Transit serves the university and general community of the Seacoast by providing fixed route, public, intercity transit between Durham and the communities of Portsmouth, Newington, Madbury, Dover, and Newmarket. Total Wildcat Transit ridership for fiscal year 2003 was 139,798 trips averaging 12 miles per passenger trip. This represents a savings of over 1,500,000 single-occupancy vehicle trips in the Seacoast region. The Campus Connector is a free fare system whose seven routes serve the immediate UNH campus and adjacent lots with high frequency service. In general, there is an active fleet of 10-12 vehicles running 7 days a week during the academic year. Summer service is dramatically reduced in both systems. Total Campus Connector ridership for fiscal year 2003 was 530,134 trips and has been growing rapidly as the university expands and develops peripheral facilities.[24] In 2003, student transportation fee funding increased resources to transit dramatically. This trend was accelerated in 2004.

The inventory calculates emissions for fuel from UNH campus pumps (to fuel all types of UNH vehicles including cars and vans) and does not include any fuel obtained from other sources. The decreasing fuel consumption of the gasoline fleet is due primarily to the recent trend to reduce fleet size and depend more on rental vehicles for fleet needs (i.e. rather than keeping vehicles on hand for departmental use, departments now often rent from Enterprise Rentals). Fuel consumption for the decade was difficult to calculate due to the complexity of reporting and documentation procedures for the fuel by the state and UNH. The only data available was from the university vehicle reports from 1994 to 1998 that listed the fuel used by each vehicle (compiled by a staff position that was eliminated in 1998). Due to this lack of data, years 1990 through 1993 were assumed to be the same as 1994. Years 1999 through 2003 were estimated from a linear regression of 1994 through 1998, assuming that the trend described above (decreasing fleet size) has continued to the present. This means that there could be some error in the estimation of fuel used by the fleet for these years. In addition to this source of error, there were also significant discrepancies between different information sources for fuel consumption. Another report, generated by the UNH Facilities Business Office[25], estimated fuel consumption at over twice the amount of the reports generated by the Transportation Department. The UNH Transportation Department is unable to account for the discrepancy.

The reports generated by the UNH Transportation Department were used in this inventory, with estimated university fleet fuel consumption accounting for about 2% of total emissions (Table 2 in Appendix). However, if the higher estimates were used, fleet fuel consumption would account for about twice that amount.

Transportation at UNH contributed 13% of the total emissions in FY03. It is UNH's third largest source of emissions and includes emissions from university fleet and transit and commuter emissions from students, faculty, and staff.

Bicycles are a vital component of UNH's Transportation Demand Management policy. The Cat Cycle program allows any member of the university community to arrive by bus or park their car for the day, and then have access to a bicycle.

University Community Commuters

Calculation of emissions from commuting habits of faculty, staff, and students were estimated to approximate the quantity of fuel burned in round trip transportation from home to UNH. Commuter habits were estimated from a survey completed in May of 2001 by the UNH Survey Center for the UNH Transportation Policy Committee and Office of Sustainability Programs. This information was used to estimate total miles traveled by faculty, staff and students for each academic year and summer months. It was assumed that commuter habits and fuel efficiency have not changed significantly since that time, so the fuel use reported in this inventory is directly correlated to the size of the university community and the findings of the 2001 survey.

The survey found that 98.8% of all faculty and staff drive an average of 4.82 days a week[26]. The average round trip commute for faculty is 27 miles[27]. An average of 36% of students drive to UNH 3.18 times per week. The round trip average for students was estimated to be 12 miles[28].

The estimation of the university community's daily commute is the section with the greatest uncertainty. The survey used to approximate habits was asked of 400 students (3.3% of all students) and 400 faculty/staff (16% of all personnel). The emissions from this section add up to 11% of the total UNH emissions; this estimation could be in error by several percent.

As a component of UNH's TDM, the Amtrak Downeaster train has provided an alternative to driving. Although emissions were not estimated for the Amtrak service (it has only been in operation since December 2001), it is important to highlight that the train is continuing to increase its ridership. During March 2004, approximately 1,300 individuals departed and arrived at the UNH Durham station. This is an increase of 105% from March 2003[28a].

The Amtrak Downeaster Durham station was opened in 2001 and continues to increase its ridership and thereby provide an alternative to travel in single-occupancy vehicles. During March 2004, approximately 1,300 individuals departed and arrived at the UNH station.

With approximately 6400 students, staff and faculty commuting daily, parking lots such as A-Lot fill up quickly.

Part II: Emissions from Waste Management

UNH produces thousands of tons of solid and liquid waste a year. In the past, the solid waste was incinerated in an on-campus facility, but since 1996 it has been landfilled. UNH's wastewater is processed with the wastewater from the town of Durham. The waste management section of this inventory is divided into these two categories: Solid Waste Disposal and Wastewater Treatment.

Solid Waste Disposal

Methane and carbon dioxide are produced from the anaerobic decomposition of organic waste in landfills by methanogenic bacteria. Only methane is accounted for in this section with the assumption that the CO_2 originates from biomass materials that will be re-grown on an annual basis[29]. Three methods of solid waste management have been employed by UNH over the past decade: incinerating, landfilling, and composting. UNH incinerated its waste in an independently-run, on-campus incinerator through 1996. The greenhouse gas emissions from this process are difficult to estimate, as they are highly dependent on the make-up of the waste and were never monitored. The emission factor used is based on an EPA report and was adjusted for the efficiency of the UNH incinerator[30]. Since 1996, UNH has contracted Waste Management[31] to manage solid waste disposal. The waste is trucked to Turnkey Landfill[32] in Rochester, NH, which produces electricity from recovered methane. The emissions from this combustion are not included in this inventory; only the uncaptured methane is included, following the US EPA guidelines. The emissions from the transport of the waste are also estimated (Table 2 in Appendix). UNH also recently began a program to compost food waste from several locations on campus and in the community. As part of the UNH Food and Society Initiative, the compost program demonstrates a viable and effective alternative to adding food waste to the wastewater stream and the landfill. Since the program began in 1998, more than 200,000 pounds of food waste have been diverted. In academic year 2003-2004, waste was collected from three campus dining halls, the Memorial Union Building, Huddleston Dining Hall, Oyster River Middle and High School, the UNH Greenhouses and poultry facility, and a local grocer, Durham Marketplace. Any methane emissions from this operation were determined to be insignificant.

Liquid Wastewater Treatment

All of UNH's wastewater goes to the Durham wastewater treatment plant and is treated aerobically before being released. Aerobic treatment does not release any methane, and so UNH's wastewater is not included in the inventory.[34]

UNH's composting program has diverted more than 200,000 pounds of food waste from the wastewater stream and landfill since beginning in 1998, thereby helping to reduce emissions during transport and at the landfill.

Part III: Emissions from Agriculture

The University of New Hampshire is a land-grant university that has valued its agricultural heritage since the late 1800s. Today UNH has ongoing teaching and research that includes dairy, poultry, swine, equine, and crop production.

Animals

As a land-grant university, UNH maintains sizable animal herds. Some domesticated animals, most notably pigs and cows, produce methane as a normal byproduct of digestion, which is known as enteric fermentation. These animals utilize bacteria to assist in the digestion of their food, which releases methane in the fermentation process[35]. Only the domesticated animals on campus were included in this inventory (dairy, swine, and equine). Methane is also released from the decomposition of animal waste. There were no perfect records of herd sizes back to 1990, and herd size fluctuates throughout the year, so counts are estimates. Since animal emissions account for only about 1% of UNH's total emissions, the year-to-year variability for university-wide emission estimates is insignificant (Table 2 in Appendix).

Soils Management (Fertilization)

Nitrous Oxide is produced from bacterial denitrification and nitrification, and fertilizing fields increases the amount of N_2O released. However, due to UNH's small amount of farmed land and the relatively low emission factors, emissions would have been well below 1% of the total emissions and were therefore ignored in this inventory.

Part IV: Emissions from Refrigerants

Refrigerants and Other Chemicals

Hydrofluorocarbons (HFCs) are used primarily as alternatives to ozone-depleting substances, such as Chlorofluorocarbons (CFCs), that are being phased out under the terms of the Montreal Protocol and Clean Air Act Amendments of 1990[36]. These substances (CFCs and HFCs), are both used at UNH in refrigeration and air conditioning units and are long-lived and active greenhouse gases (Table 1).[37] Since CFCs are monitored and are being phased out by the Montreal Protocol they are not included in greenhouse gas emission inventories. UNH is required by the US EPA to record the amount of these refrigerants that are lost during the normal recharging of the refrigeration unit and any mechanical failures (leaks) that occur. Unfortunately, these records are only available for 1995-2003, but this does not affect this inventory, as UNH did not begin using HFCs until 1997. Since even the year with the greatest emissions accounts for less than 1% of the UNH total, HFCs are not a significant source of greenhouse gas emissions (Table 2). We have tallied CFC emissions, but following the guidelines of the IPCC and US EPA, they were not included in the inventory (Table 9). If they had been included, CFC emissions would account for as much as 2% of total greenhouse gas emissions (in 1999). To our knowledge, UNH does not use any PFCs or SF_6 on campus.

Emissions from agriculture contribute approximately 1% of UNH's total emissions and accounts for emissions from UNH's dairy, swine, and equine herds. These animals are critical to UNH's teaching and research endeavors. Each year through the UNH Cream Program (Cooperative for Real Education in Agricultural Management), 20 students are given responsibility for a 26 cow milking herd.

Conclusions and Recommendations

General

- **UNH is Making Progress.** UNH has initiated policies that reduce emissions in its campus operations. Despite a growing population of faculty, staff, and students, greenhouse gas emissions have increased at a significantly slower rate than the national average. This was primarily due to a shift from carbon-intensive energy production (such as an incinerator) to natural gas use on campus and energy efficiency projects of the UNH Energy Office. According to a study completed by the US Department of Energy, the efficiency projects undertaken by the UNH Energy Office save $4 million a year (compared to other schools in UNH's peer group in 2000) in reduced consumption.

- **Energy Consumption Continues to Increase.** Energy consumption and greenhouse gas emissions have increased over the past fourteen years due to infrastructure expansion and added air conditioning. This increase now outpaces efficiency upgrades and behavioral changes resulting from educational efforts.

- **Sustainability Makes Financial Sense.** As a result of rigorous financial and environmental analysis, the UNH Board of Trustees approved the construction of a combined heat and power facility (CHP) slated to come on line in the fall of 2005. Calculations of emissions under the CHP scenario beginning in 2005 project a 40% decrease in the university's greenhouse gas emissions. This level of emissions reduction will move UNH well beyond internationally agreed upon reduction targets including those established by the New England Governors and Eastern Canadian Premiers Climate Action Plan. Importantly, these emissions reductions will be achieved with existing technology deployed through a financially-sound business model thereby improving public and environmental health as well economic productivity and competitiveness.

Source-Specific

On-campus Stationary Sources

- **Conclusion:** The production of energy on campus, referred to as "on-campus stationary sources," is the largest producer of emissions, 49% in fiscal year 2003 (Table 6). The majority of emissions from on-campus stationary sources occur through the combustion of fossil fuels in the Central Heating Plant to produce steam and hot water.

- **Recommendation:** 1) UNH should maintain its commitment to build the combined heating and power facility (CHP) that will supply the university with energy-efficient heat and electricity. This type of plant uses heat produced in electric generation to heat and cool buildings. This local energy production technology avoids the larger waste heat losses (typically 60%) at large utility power plants. 2) UNH should broaden the reach of educational efforts to further reduce the on-campus stationary source emissions directly through changes in the behavior of UNH's community members.

Purchased Electricity

- **Conclusion:** The production of energy off campus through electric power generation is the second largest contributor of greenhouse gas emissions, 37% in fiscal year 2003 (Table 6). UNH purchases its electricity from the New England pool of energy providers and in 2003 purchased 57,844,401 kilowatt hours. Even with the new CHP facility, UNH will still need to purchase 10-20% of its electricity. The fuels used to produce this electricity in New England since the early 1990s have shifted to less carbon intensive fuels (e.g. natural gas, hydroelectric, and nuclear energy). Renewable energy sources account for approximately 0% of the energy market available to UNH.

- **Recommendation:** Despite the anticipated reduction in purchased electricity and the deregulation of the electric market, UNH should factor the educational and social benefits of cleaner power into the decision of what kind of electric production methods to support such as renewable energy sources (biomass, solar, wind, etc.). The CEI Working Group in conjunction with university officials should conduct an analysis of options for green energy procurement available under the recently deregulated energy market and provide recommendations to the UNH administration. Options should include financial analysis of forming or joining a green energy purchasing consortium.

Transportation (Commuting Students, Faculty/ Staff and Transit)

- **Conclusion:** Transportation at UNH is the third largest contributor of greenhouse gas emissions, 13% in fiscal year 2003 (Table 6). The emissions result from the daily commuting habits of students, staff, and faculty as well as the operation of UNH's two transit systems. With approximately 2,800 faculty and staff commuting daily, and an additional 4,000 students commuting 3.5 times a week to campus, transportation via single-occupancy vehicles is a community-wide concern. Since adopting a Transportation Demand Management (TDM) policy, policy performance and efficiency has improved through a wide variety of projects undertaken by UNH Transportation Services and Campus Planning. However, full policy implementation has been notably slowed by two factors: 1) faculty contract negotiations nullified a tiered pricing system for campus parking improvements, 2) limited implementation of transportation policies by the Town of Durham called for under its 2002 master plan update.

- **Recommendation:** 1) UNH should continue to incorporate principles of Transportation Demand Management (TDM) into decisions made regarding all forms of transportation and campus development. TDM is a tool to maximize mobility while reducing congestion and the resulting pollution. TDM includes: an efficient transit system, car pooling, parking management strategies, alternative mode incentive programs, bicycles and pedestrian infrastructure enhancements, and housing and scheduling management. 2) The university fleet should continue to replace its diesel-burning fleet with more advanced sustainable technologies such as compressed natural gas, low sulfur–low emission diesel or electric/hybrid technologies. Diesel that remains part of the UNH fleet should be biodiesel sourced and regionally produced. 3) An aggressive education campaign to address the "car culture" mentality should occur to emphasize the availability of other choices such as transit, carpooling, and cycling including regional intercity transit and rail travel options. 4) Work with the Town of Durham to fully implement its transportation policies as called for under the town's 2002 master plan update.

Agriculture, Solid Waste, and Refrigerants

- **Conclusion:** This category makes up a small percentage of UNH's emissions, less than 1.5% in fiscal year 2003. The category includes emissions from UNH's dairy, swine, and equine facilities in addition to estimating emissions from solid waste deposited in landfills. In 2002 and 2003, there were no emissions from refrigerants. Prior to 1996, all of UNH's solid waste was incinerated on campus, now it is trucked to a landfill in Rochester, NH. The yearly average of solid waste from the years 1997 to 2003 is 2,000 metric tons.

- **Recommendation:** Agriculture: UNH should pursue viable opportunities to capture methane from agriculture (dairy, equine, and swine) for energy use. Solid Waste: Continue to pursue integrated waste management to reduce waste streams and improve recycling efficiency.

Since 1999, more than 400 students have completed the UNH course Global Environmental Change (EOS 405). As part of this course, undergraduate students participate in a negotiation to reduce greenhouse gas emissions at UNH. Through the negotiations, students submit recommendations for emission reductions based on their analysis of UNH's greenhouse gas emissions.

Community

UNH Policy

- **Conclusion:** UNH energy policy, including the efficiency projects of the Energy Office have to date been driven largely by economics and technology. However, two factors point to the importance of placing UNH energy policy in a broader educational context. First, energy demand will likely continue to increase without purposeful policies to mitigate that trend that include an explicit community ethic to conserve energy. Second, with the establishment of the Office of Sustainability Programs in 1997, UNH has committed itself to a university-wide educational goal of ensuring that all of its graduates develop the competence and character to advance sustainability in their civic and professional lives. This educational goal can only be achieved through modeling energy efficiency and other greenhouse gas reduction policies and integrating those practices into teaching, research, and engagement activities of the university.

- **Recommendation:** 1) UNH should continue aggressive efforts to increase its energy efficiency and reduce its emissions in all areas. 2) UNH should approach energy decisions keeping in mind not only direct financial costs, but also the environmental and educational effects of efficient energy production and consumption. 3) UNH should incorporate sustainability into implementation of all aspects of the recently updated campus master plan including sustainable design and construction principles, projects of the Campus Energy Office, transportation Demand Management and sustainable landscaping.

Education

- **Conclusion:** The educational goals of the Climate Education Initiative can only be achieved by integrating the *why* and *how* of greenhouse gas reductions across the teaching, research, operations and engagement activities of the UNH land grant mission.

- **Recommendation:** 1) UNH should continue its strong commitment to the *climate protection campus* as part of its community identity, and work with the Climate Education Initiative Working Group to track progress towards long-term goals using CEI indicators. 2) UNH should incorporate emission reduction education, expectations, and concrete guidelines into its Freshman orientation activities both online and on-campus.

Footnotes

[1] See the section entitled "How do you Measure Grennhouse Gases?" for an explanation.

[2] The IPCC, established in 1988, was created by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) with the recognition that the Earth's climate may be changing. The IPCC completed its First Assessment Report in 1990, which played an important role in establishing the Intergovernmental Negotiating Committee for a UN Framework Convention on Climate Change (UNFCCC) by the UN General Assembly. The role of the IPCC is not to carry out research but to assess the "scientific, technical, and socio-economic information relevant for understanding the risk of human-induced climate change." Three working groups have been formed, to assess the science, impacts, and possible mitigation of climate change. Each group produces a report every five years; the most recent were released in the spring of 2001. http://www.ipcc.ch. Greenhouse gas emissions inventory guidelines can be found at www.ipcc-nggip.iges.or.jp

[3] The Earth's climate system comprises the atmosphere, oceans, biosphere, cryosphere, and geosphere. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2001*, 2003 U.S. E.P.A. http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf

[4] *Climate Change and New Hampshire*, US EPA, 1997 http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsStateImpactsNH.html

[5] *Summary for Policymakers, A Report of Working Group I of the Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc-wg2.org/index.html

[6] *Summary for Policymakers, A Report of Working Group I of the Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc-wg2.org/index.html

[7] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2001, 2003 U.S. E.P.A. http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf Methane GWP includes the direct effects and those effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO2 is not included. HFC-404a is a mixture of HFC-125, HFC-143a, and HFC 134a.

[8] HFC-404a is a mixture of HFC-125 (44%), HFC-143a (52%), and HFC 134a (4%). Personal Communication, Linwood Marden, Heating/Air Conditioning Specialist, UNH Facilities, 603.862.2658

[9] *Summary for Policymakers, A Report of Working Group I of the Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc-wg2.org/index.html

[10] *Climate Change and New Hampshire*, US EPA, 1997, http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsStateImpactsNH.html

[11] *Summary for Policymakers, A Report of Working Group I of the Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc-wg2.org/index.html

[12] *Climate Change and New Hampshire*, US EPA, 1997, http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsStateImpactsNH.html

[13] *Climate Change 2001: Impacts, Adaptation, and Vulnerability, Summary for Policymakers, A Report of Working Group II of the Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc-wg2.org/index.html

[14] *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, IPCC http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

[15] Personal Communication, Jim Dombrosk, UNH Energy Office, jim.dombrosk@unh.edu

[16] *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation* (GREET) Model 1.5a, Argonne National Laboratory, U.S. Department of Energy, Michael Wang, mqwang@anl.gov http://www.ipd.anl.gov/instplan/index.html

[17] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2001*, 2003 U.S. E.P.A. http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf

[18] *Annual emissions and Fuel Consumption for an "Average" Light Truck*, US EPA, 1997 http://www.epa.gov/otaq/consumer/f97037.pdf

[19] UNH Energy Office, http://www.energy.unh.edu

[20] Report from the US Department of Energy Oak Ridge Lab, data provided by the UNH Energy Office http://eber.ed.ornl.gov/commercialproducts/CCAS9798.htm. UNH does not appear in the official report as UNH Energy Manager Jim Dombrosk requested that the DOE analyze UNH independently.

[21] Public Service of New Hampshire, http://www.psnh.com

[22] ISO-NE 1998-1999 *Annual Reports*, http://www.iso-ne.com/about_the_iso/

[24] Personal Communication, 2004, Steve Pesci, Special Projects, Campus Planning and Transportation Services, spesci@cisunix.unh.edu

[25] This report was based on a file sent from the NH Department of Transportation, 603.271.2056

[26] This figure includes carpooling, which is counted as 1/2 trip. Personnel Communication, Andrew Smith, UNH Survey Center, andrew.smith@unh.edu, http://www.unh.edu/survey-center/index.html

[27] Estimation from records received from the UNH Human Resources Department, Toni Searles, Human Resources, UNH, 603.862.0516

[28] It was assumed that most off campus students live within 6 miles of Durham, which includes, Lee, Dover, Newmarket, and others.

[28a] UNH Campus Planning report, UNH Durham Ridership, 5/13/2004.

[29] *New Hampshire 1993 Greenhouse Gas Emissions Inventory*, NH DES, 1997 http://www.des.state.nh.us/ard/ghgi

[30] *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste*, US EPA, 1998, www.epa.gov/epaoswer/non-hw/muncpl/ghg/greengas.pdf

[31] Waste Management, phone: 713.512.6200 http://www.wastemanagement.com/

[32] Turnkey Landfill, phone: 603.330.0217

[34] Personal. Communication Clara Reed, Durham Wastewater Plant, 603.868.2274 www.ci.durham.nh.us

[35] New Hampshire 1993 Greenhouse Gas Emissions Inventory, NH DES, 1997 http://www.des.state.nh.us/ard/ghgi

[36] United Nations Environment Program, *Handbook for the International Treaties for the Protection of the Ozone Layer*, 6th Version 2003, http://www.unep.org/ozone/publications/Handbook-2003.pdf, US EPA, Clean Air Act, http://www.epa.gov/oar/caa/contents.html

[37] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2001*, 2003 U.S. E.P.A., http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf

Appendix

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
On-Campus Stationary Sources	24,776	22,898	27,182	25,616	27,287	24,563	34,499	33,114	30,926	30,030	27,487	30,849	27,742	35,366
Electricity	23,827	22,465	20,422	17,250	16,206	17,879	22,111	25,611	26,479	22,972	21,804	24,067	25,539	25,977
Faculty/Staff Commuters	4,408	4,431	4,474	4,613	4,775	4,773	4,717	4,705	4,664	4,903	4,896	5,144	5,404	5,459
Students Commuters	2,097	2,066	2,166	2,204	2,269	2,278	2,253	2,287	2,251	2,236	2,233	2,149	2,264	2,288
University Fleet	1,183	1,183	1,183	1,183	1,183	1,163	1,153	1,089	1,150	1,105	1,091	1,077	1,063	1,049
Wildcat Transit	335	335	335	335	335	410	349	340	423	403	413	423	433	444
Animals	658	658	658	658	658	659	665	661	656	654	659	737	721	725
Solid Waste	0	0	0	0	0	0	0	235	227	258	221	236	236	236
Refrigeration	0	0	0	0	0	0	0	0	42	3,611	76	14	22	0
Total	**56,950**	**53,702**	**56,086**	**51,525**	**52,378**	**51,314**	**65,399**	**67,702**	**66,394**	**65,769**	**58,468**	**64,273**	**62,991**	**71,100**

Table 2: Total UNH Direct Greenhouse Gas Emissions (Metric Tons Carbon Dioxide Equivalents)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
On-Campus Stationary Sources	27,525	25,401	30,320	28,503	30,514	27,466	39,061	39,919	37,829	34,972	31,925	36,403	32,653	41,417
Electricity	27,937	26,510	24,432	21,222	20,147	21,959	26,640	30,018	30,722	27,136	26,114	29,154	30,937	31,468
Faculty/Staff Commuters	5,545	5,574	5,628	5,803	6,006	6,004	5,934	5,918	5,867	6,167	6,158	6,470	6,797	6,866
Students Commuters	2,637	2,599	2,725	2,773	2,855	2,865	2,835	2,876	2,831	2,812	2,809	2,703	2,848	2,878
University Fleet	1,477	1,477	1,477	1,477	1,477	1,450	1,438	1,359	1,432	1,377	1,359	1,341	1,323	1,305
Wildcat Transit	413	413	413	413	413	505	430	419	521	496	509	522	534	547
Animals	658	658	658	658	658	659	665	661	656	654	659	737	721	725
Solid Waste	0	0	0	0	0	0	0	235	227	258	221	236	236	236
Refrigeration	0	0	0	0	0	0	0	0	42	3,611	76	14	22	0
Total	**65,778**	**62,219**	**65,240**	**60,437**	**61,657**	**60,403**	**76,572**	**80,988**	**79,606**	**76,988**	**69,321**	**77,058**	**75,537**	**84,895**

Table 3: Total UNH Direct and Upstream Greenhouse Gas Emissions (Metric Tons Carbon Dioxide Equivalents)

		Energy Consumption TJ	CO_2 Metric Tonnes	CH_4 Kg	N_2O Kg	HFC Kg	Imperial Tons CO_2 Equivalent	Metric Tonnes CO_2 Equivalent
	Solid Waste			0			260	236
	Animals			34,944			799	725
	Refrigeration					0	0	0
	On-campus Stationary Sources	489	35,268	373	290		38,973	35,366
	Electricity	634	25,910	296	195		28,627	25,977
Transport	Buses	6	409	56	10		455	444
	University Fleet	16	1,025	149	67		1,156	1,049
	Commuting Students	33	2,202	3,517	253		2,521	2,288
	Commuting Faculty/Staff	79	5,254	812	605		6,015	5,459
	Total Transport	127	8,481	4,478	925		9,693	8,796
Total		**1,250**	**69,660**	**5,148**	**1,411**	**0**	**78,352**	**71,100**

Table 6: UNH's Greehouse Gas Emissions, by Mass and MTCDE, Fiscal Year 2003

Fuel	Metric Tonnes Carbon / MMBtu
Residual Fuel Oil (#6)	0.02149
Distillate Fuel Oil (#2)	0.01995
Natural Gas	0.01447
Propane	0.01699
Incinerator	0.02712

Table 8: Carbon emission coefficients for various fuels burned on campus[1]

Fiscal Year	CFC-11 GWP=3,800		CFC-12 GWP=8,100		CFC-113 GWP=4,800		CFC-502 GWPUnknown	Total Emissions From CFC's
	kg	MTCDE	kg	MTCDE	kg	MTCDE	kg	MTCDE
1995	0	0	301	1,145	0	0	40	1,145
1996	0	0	359	1,363	0	0	15	1,363
1997	0	0	62	234	0	0	0	234
1998	0	0	73	276	0	0	585	276
1999	440	1,672	92	351	0	0	134	2,023
2000	0	0	48	184	0	0	7	184
2001	0	0	45	99	0	0	0	99
2002	0	0	6	13	0	0	0	13
2003	0	0	0	0	0	0	0	0

Table 9: Emissions of CFCs used at UNH, 1995-2003

Emissions and GWP for CFCs are included for reference only, they are not included in the inventory following the protocol of the IPCC. Records were only available from after 1995, there were likely additional CFC emissions prior to 1995 that are not documented here. All emissions were the result of mechanical failure or mistakes -- there were no intentional releases. No PFCs have been used at UNH. Source: Gary Hall, Supervisor of Electrical and Mechanical Services, gary.hall@unh.edu, 603-862-2658

Fiscal Year	Purchased Electricity	On Campus Stationary Sources					Transportation		
		#6 Fuel Oil (residual oil)	#2 Fuel Oil (distillate oil)	Natural Gas	Propane	Incinerator Steam	University Vehicles		
							Gasoline Fleet	Diesel Fleet	University Buses
	kWh	Gallons	Gallons	MMBtu	Gallons	1000 lbs steam	Gallons	Gallons	Gallons Diesel
1990	43,344,000	1,544,389	224,138	0	75,646	92,432	86,260	15,222	33,027
1991	43,000,000	1,314,642	273,998	0	99,145	93,423	86,260	15,222	33,027
1992	43,518,428	1,613,052	388,894	0	110,775	81,953	86,260	15,222	33,027
1993	44,105,455	1,328,082	368,527	0	292,255	100,611	86,260	15,222	33,027
1994	43,767,261	1,516,882	374,892	0	331,965	82,413	86,260	15,222	33,027
1995	45,033,744	1,325,604	326,077	0	364,016	78,455	79,031	12,167	40,387
1996	51,098,096	2,222,010	406,599	0	527,420	27,885	81,690	14,736	34,380
1997	50,875,573	1,365,888	355,716	196,311	274,507	0	77,033	13,023	33,487
1998	48,903,360	1,197,672	234,946	234,059	84,637	0	71,352	16,477	41,610
1999	49,859,266	1,984,078	174,488	80,327	84,456	0	69,533	15,335	39,658
2000	50,462,168	1,882,100	132,085	66,349	75,281	0	66,352	15,672	40,685
2001	53,591,328	1,846,953	161,516	122,136	89,593	0	63,166	16,008	41,711
2002	56,868,538	1,674,540	165,823	102,716	86,6430	0	59,985	16,344	42,738
2003	57,844,401	2,250,493	188,840	113,597	105,533	0	56,803	16,681	43,764

Table 10: UNH Energy Use Summary, By Fuel

On-campus stationary sources and electric fuel consumption values from UNH Energy Office (Jim Dombrosk 603.862.2345, Jim.Dombrosk@unh.edu) Fleet Fuel Consumption values for 1990-1993 and 1999-2000 were unavailable. Fuel consumption values for 1990-1993 are assumed to be the same as 1994 values. Values for years 1999-2000 are from a linear regression of years 1994-1998, assuming that the trend to reduce fleet size and mileage has continued to the present. Equations are as follows: [Gasoline Fleet $y = -3181.4x + 101343$ Diesel Fleet $y = 336.6x + 11969$ University Buses $y = 1026.6x + 29392$] Fuel consumption values 1994-1998 from State of New Hampshire Motor Vehicle Reports, 1994-1998. The reports are archived at the UNH Garage, Harold Knowles, 603.862.2746. The reports did not differentiate between gasoline and diesel vehicles. It was assumed that all Mid and Heavy weight vehicles used diesel fuel, and all lightweight trucks and cars used gasoline. This assumption was checked with a sample of 20 vehicles and was accurate. In the 2001-2003 update, total gallons were not still not available, due to reporting and billing procedures by the state and UNH, thus the linear regression equations were used.

Fiscal Year	Hydro-electric	#2 Fuel oil (Distillate Fuel)	Nuclear	Coal	Natural gas	#6 Fuel Oil (Residual Oil)	Other	Non-Hydro Imports
1990	6.4%	1.1%	31.7%	15.4%	5.1%	33.8%	0.0%	6.4%
1991	8.1%	1.1%	32.5%	15.6%	6.4%	31.7%	0.0%	4.6%
1992	10.1%	0.8%	33.2%	16.2%	10.0%	25.8%	2.4%	1.5%
1993	10.9%	0.3%	37.6%	15.9%	12.5%	17.6%	5.2%	0.0%
1994	11.3%	0.2%	38.2%	15.2%	14.2%	14.0%	5.5%	1.3%
1995	11.2%	0.4%	34.0%	15.5%	17.1%	11.3%	5.3%	5.2%
1996	11.8%	0.8%	28.9%	16.2%	17.7%	10.6%	5.3%	8.8%
1997	12.5%	1.8%	20.3%	17.4%	17.3%	15.2%	5.4%	10.2%
1998	12.8%	2.2%	16.0%	16.8%	16.4%	20.8%	5.3%	9.7%
1999	12.7%	1.5%	21.1%	14.4%	15.7%	20.8%	5.2%	8.7%
2000	11.8%	0.6%	25.7%	14.3%	16.4%	16.5%	5.6%	9.1%
2001	9.9%	0.0%	26.8%	14.5%	21.9%	13.5%	5.9%	7.9%
2002	9.9%	0.0%	26.8%	14.5%	21.9%	13.5%	5.9%	7.9%
2003	9.9%	0.0%	26.8%	14.5%	21.9%	13.5%	5.9%	7.9%

Table 11: Sources of Electric Production by Percent, 1990-2003

Consumption and Sources of UNH's electricity, by year. Consumption values provided by the UNH Energy Office (Jim Dombrosk, 603.862.2345 Jim.Dombrosk@unh.edu). Fiscal year values were calculated by averaging the two years involved (i.e. FY 1991 is an average of calendar years 1990 and 1991). This table does not include "pumped storage" as the emissions associated with this source are included in the other sources. The pumped storage electrical generation was removed and new percentages found from the new total generation. "Hydroelectric" includes power generated from hydroelectric plants inside of New England and Hydro-Quebec combined. "Residual oil" includes small amounts of generation from wood in 1989 and 1990. "Other" principally includes generation from wood and refuse and includes a small amount of start-up oil. "Non-Hydro Imports" represents non-hydroelectric purchases from non-NEPOOL sources outside of New England. Those purchases usually occur during peak power use periods when NEPOOL facilities cannot generate all the electricity required by the grid. Hydroelectric imports (Hydro-Quebec) are included in "Hydroelectric." Source: The ISO New England 1998-1999 Annual Reports http://www.iso-ne.com/about_the_iso/ and personal communication with Paul Shortley pshortely@iso-ne.com for Hydro-Quebec import information. 2000 Data from a ISO-NE System Planning Power Source Report. Mark Babula, Supervisor, Power Supply and Reliability, mbabula@iso-ne.com

Fiscal Year	A Fall/Spring Students	B Trips / Day	C Days/ Year	D Miles/ Trip	E Fall/Spring Miles/Year	F Summer School Students	G Trips/ Day	H Days/ Year	I Miles/ Trip	J Summer Miles/Yea	K Total Miles/Year
					E=AxBxCxD					J=FxGxHxI	K=E+J
1990	4,164	0.64	154	12	4,924,846	3,150	1	35	12	1,323,000	6,247,846
1991	4,128	0.64	154	12	4,882,268	3,150	1	35	12	1,323,000	6,205,268
1992	4,275	0.64	154	12	5,056,128	3,150	1	35	12	1,323,000	6,379,128
1993	4,413	0.64	154	12	5,219,343	3,150	1	35	12	1,323,000	6,542,343
1994	4,463	0.64	154	12	5,278,479	3,150	1	35	12	1,323,000	6,601,479
1995	4,506	0.64	154	12	5,329,336	3,150	1	35	12	1,323,000	6,652,336
1996	4,469	0.64	154	12	5,285,576	3,150	1	35	12	1,323,000	6,608,576
1997	4,483	0.64	154	12	5,302,134	3,150	1	35	12	1,323,000	6,625,134
1998	4,395	0.64	154	12	5,198,054	3,150	1	35	12	1,323,000	6,521,054
1999	4,269	0.64	154	12	5,049,032	3,150	1	35	12	1,323,000	6,372,032
2000	4,307	0.64	154	12	5,093,975	3,150	1	35	12	1,323,000	6,416,975
2001	4,081	0.64	154	12	4,826,680	3,150	1	35	12	1,323,000	6,149,680
2002	4,292	0.64	154	12	5,076,234	3,150	1	35	12	1,323,000	6,399,234
2003	4,463	0.64	154	12	5,278,479	3,150	1	35	12	1,323,000	6,601,479

Table 12: Calculation of Miles Traveled by Student Commuters

Column A is a total commuting student count (Student data is recorded from the fall of each year, excluding graduate continuing education students and is recorded as Full-time equivalent students, a part time student is considered to be 1/2 student, UNH Institutional Research, http://www.unh.edu/ir) 36% of Students commute in cars to Durham, UNH Transportation Survey, May 2001, UNH Survey Center. Column B: Commuting Students are assumed to drive 0.64 trips from home to school a weekday (3.18 trips a week). UNH Transportation Survey, May 2001. Commuter habits were assumed to not change over time. Column C: Number of days of class/exams counted from 2000/2001 UNH calendar. Column D: Estimated length of roundtrip, average distance from Newmarket and Dover. Column E: Total School year miles traveled. Column F: Total number of summer school students, (Nancy Hamer, Department of Continuing Education, n_hamer@unhf.unh.edu.) Column G: Students are assumed to drive one trip from home to school a weekday. Column H: Days per year is average length of four summer school sessions from 2001 summer schedule. Column I: : Estimated length of roundtrip, average distance from Newmarket and Dover. Column J: Total summer school miles traveled. Column K: Total year miles traveled.

Fiscal Year	A Total Commuting Faculty that Drive	B Trips/Day	C Days/Year	D Miles/Trip	E Miles/Year
	98.8% of all Faculty				E=AxDxExF
1990	696	0.96	154	27	2,778,209
1991	699	0.96	154	27	2,790,184
1992	704	0.96	154	27	2,810,143
1993	720	0.96	154	27	2,874,010
1994	727	0.96	154	27	2,901,951
1995	715	0.96	154	27	2,854,051
1996	721	0.96	154	27	2,878,001
1997	728	0.96	154	27	2,905,943
1998	734	0.96	154	27	2,929,893
1999	729	0.96	154	27	2,909,935
2000	720	0.96	154	27	2,874,010
2001	722	0.96	154	27	2,881,993
2002	751	0.96	154	27	2,997,752
2003	783	0.96	154	27	3,125,485

Table 13: Calculation of Miles Traveled by Instructional Faculty

Column A: 98.8% of UNH Full Time Instructional faculty with benefits, Budgeted and non-budgeted by fulltime equivalent (USNH Factbooks, secton III 89-02 USNH HR Office). Available online at http://usnhopa.unh.edu. 98.8% of Faculty are assumed to drive, UNH Transportation Survey, May 2001, UNH Survey Center. Column B: Personnel are assumed to drive a roundtrip from home to UNH four (4.82) days a week (4.82 trips a week / 5 days a week = 0.96 Trips/day). UNH Transportation Survey, May 2001, UNH Survey Center. Commuter habits were assumed to not change over time. Column C: Days of class/exams counted from 2000-2001 UNH calendar. Column D: Faculty commuting distance calculated from address data (UNH Human Resources) Column E: Total Miles traveled.

Fiscal Year	A Total Commuting Staff that Drive	B Trips/Day	C Days/Year	D Miles/Trip	E Miles/Year
	98.8% of all Staff				E=AxDxExF
1990	1,658	.96	241	27	10,357,062
1991	1,684	.96	241	27	10,519,476
1992	1,659	.96	241	27	10,363,308
1993	1,732	.96	241	27	10,819,319
1994	1,759	.96	241	27	10,987,980
1995	1,775	.96	241	27	11,087,928
1996	1,754	.96	241	27	10,956,747
1997	1,717	.96	241	27	10,725,618
1998	1,694	.96	241	27	10,581,944
1999	1,771	.96	241	27	11,062,941
2000	1,792	.96	241	27	11,194,122
2001	1,895	.96	241	27	11,837,534
2002	1,965	.96	241	27	12,274,805
2003	2,021	.96	241	27	12,624,621

Table 14: Calculation of Miles Traveled by Staff

Column A: 98.8% of UNH Full Time PAT and OS Staff with benefits, Budgeted and non-budgeted by fulltime equivalent (USNH Factbooks, secton III 89-02 USNH HR Office). Available online at http://usnhopa.unh.edu. 98.8% of Faculty are assumed to drive, UNH Transportation Survey, May 2001, UNH Survey Center. Column B: Personnel are assumed to drive a roundtrip from home to UNH four (4.82) days a week (4.82 trips a week / 5 days a week = 0.96 Trips/day). UNH Transportation Survey, May 2001, UNH Survey Center. Commuter habits were assumed to not change over time. Column C: (52 weeks / year) x (5 workdays / week) - (14 UNH holidays/ year) - (5 sick/personal days) = 241 working days / year. Column D: Faculty commuting distance calculated from address data (UNH Human Resources) Column E: Total Miles traveled.

Fiscal Year	Agriculture				Waste	Refrigeration	
	Cows				Solid Waste Management	HFC-134A Emissions	HFC-404A Emissions
	Dairy Cows	Heifers	Pigs	Horses			
	Head Count	Head Count	Head Count	Head Count	Metric Tonnes	Kg	Kg
1990	100	125	104	30	2,015	0	0
1991	100	125	104	30	1,475	0	0
1992	100	125	104	30	1,574	0	0
1993	100	125	104	30	1,531	0	0
1994	100	125	104	30	1,531	0	0
1995	100	125	105	30	2,094	0	0
1996	100	125	122	30	1,751	0	0
1997	100	125	112	30	1,994	0	0
1998	100	125	99	30	1,926	6.6	0
1999	100	125	92	30	2,187	4.4	226.6
2000	100	125	94	30	1,872	6.6	2.2
2001	130	103	123	30	2,005	1.8	1.2
2002	130	103	78	30	2,000	7.6	0
2003	130	103	90	30	2,000	0	0

Table 15: UNH Agricultural, Solid Waste and Refrigerant Data

Agriculture - Headcount of UNH animal herds for the past decade. Pig Headcount from pre-1995 was unavailable so an average of herd from 1995-2000 was used. Herd size has remained "about the same" over this time period (UNH Pig Farm, Tom Oxford 603.659.2216). Cow headcount is an average herd size from 1990 – 2000. Herd size has remained "fairly constant" over this time period. (UNH Dairy Barn, Tina Savage, 603.862.1027). Horse headcount include UNH owned horses and boarding horses. (UNH Horse Barn, Manager, Sue Bruns 603.862.0027). **Total UNH Solid Waste Produced**. Tonnage includes all UNH waste not recycled except construction waste that was handled by the contractor. Years 1990, 1993-1994 were unavailable, so an average from an internal recycling memo (1 Feb 93) based on years 1980 through 1992 was used. Any small errors due to this lack of data are insignificant, since emissions from more waste than UNH produced was included in the energy section for the years the incinerator was in use. After 1990, an average of 24% of this waste was recycled and is not included as incinerated trash [2,015 - (2,015 x 24%)=1,531] All solid waste was sent to Turnkey Landfill during years 1997-2000 and was not incinerated. The emissions from waste incineration years 1990-1996 are included on in the "On-campus Stationary Sources" Section. Waste tonnage from: Annual Updates, UNH Recycling Office, 603.862.3100. **Refrigerants** - Emissions from UNH refrigerants. Data was available for 1995-2003 only, but this will not affect the inventory, as HFCs were not used on campus until 1997. There were likely additional CFC emissions prior to 1995 that are not documented here. All emissions were the result of mechanical failure or mistakes -- there were no intentional releases. No PFCs have been used at UNH. Source: Gary Hall, Supervisor of Electrical and Mechanical Services, gary.hall@unh.edu, 603-862-2658.

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