Method for Conducting a Greenhouse Gas Emissions Inventory for Colleges and Universities

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Introduction

This report provides guidance for academic institutions and other like organizations seeking to quickly and inexpensively create a greenhouse gas (GHG) emissions inventory of their operations. The inventory method presented here is intended to aide institutions in identifying and documenting the sources of GHG emissions attributable to their activities. A completed inventory becomes the foundation of an information repository upon which future inventory efforts, appropriate emissions targets, and strategies for action can be organized.

In particular, this document provides:

- an introduction and background to climate change and GHG emissions – a presentation of the most salient issues, description of most relevant GHGs, and definitions of terminology;

- procedures for implementing the inventory effort - the goal and scope definition which determines the boundary and functional unit of the inventory, for example emissions per student;

- description of the typical dominant emissions found at universities and a discussion of sources - including an outline of the data categories identified relevant to GHGs emissions by universities;

- identification of lessons learned by Tufts University and other institutions while conducting a GHG inventory; and

- generic spreadsheets – to facilitate the inventory effort at your institution.

There are many reasons to embark upon the GHG inventory effort. Most obviously, it is a tool to assist in the systematic identification and recording of known and unknown sources of GHG emissions at an institution. An indirect benefit of conducting an inventory is the knowledge gained of the structure and operation of the institution, not only for GHG emissions, but other emissions and environmental stressors.

Second, the inventory will provide a benchmark against which improvements can be quantified. Essential to justifying the commitment of resources (i.e. spending money) is an estimation of the quantities of emission reduced related to a specific effort - how much will the effort reduce emissions in units of carbon equivalents and what will it cost? Quantifying the effectiveness of actions that reduce energy and material use and that lead to reductions of emissions will assist in the justification of resources.

Third, the inventory will be a reference to communicate the most important, as well as the not so obvious, emission releases. Information gathered in the inventory will be used to generate charts and graphs that summarize the importance and status of the emissions reduction effort at your institution. Further, the inventory will assist in the identification of the aggregate impact of the many actions, small and large, that emit greenhouse gases. While the environmental impact of one light bulb, one meal or one photocopy is difficult to value, the cumulative effect of everyday actions creates a substantial ecological footprint. For example, in 1990 Tufts University, an academic institution of 8000 graduate and undergraduate students, served 5 million meals; made 14 million photocopies; used 65 tons of paper towels, consumed 110 million gallons of water and 23 million (kWh) of electricity; generated over 2000 tons of solid waste; and released more than 15,000 metric tones carbon equivalents (MTCE) of GHGs (Creighton 1996) (Gloria 2001). Each source of emission, identified collectively, communicates the importance of an institution's commitment to reduce its contribution to global climate change.

Background to Climate Change and Greenhouse Gas Emissions

Introduction to climate change and relevant anthropogenic activities.

Molecules found in the Earth's atmosphere act as "greenhouse gases." When light strikes the Earth's surface, some of the sunlight is reflected as infrared radiation (heat). Greenhouse gases tend to absorb part of this infrared radiation as it is reflected back towards space, trapping the heat in the atmosphere.

Many gases exhibit such "greenhouse" properties, including those that occur naturally in the atmosphere, such as water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and those that are man-made, such as chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and perfluorocarbons, and sulfur hexafluoride (SF_6).

Since the beginning of the industrial revolution, the combustion of fossil fuels and other human activities have increased the atmospheric concentrations of greenhouse gases and have enhanced the heat-trapping capability of the earth’s atmosphere. As a result, the planet is heating at a faster rate than at any time in the last 10,000 years. Eleven of the hottest years in recorded history have occurred since 1983. The decade of the 1990s was the hottest in the 20th century. Rising global temperatures are expected to raise sea level, and change precipitation and other local climate conditions. Changing regional climate is projected to alter forests, crop yields, water supplies and affect human health, animals, and many types of ecosystems.

An important first step in reducing and avoiding emissions is to better understand the activities associated with an institution’s contribution to climate change by creating a greenhouse gas emissions inventory.

Implementing the Inventory Effort

An emissions inventory is useful in estimating future trends of and determining appropriate opportunities within an institution's operations for emissions reductions.

The inventory process presented here consists of four general steps:

1. Determination of the goal and scope of the inventory. This includes determination of the inventory boundary and metrics of measurement.
2. Data Collection - identification and recording of quantities and activities associated with the release of GHGs.
3. Calculation of GHG quantities and conversion to CO_2 equivalents based on global warming potential (GWP).
4. Interpretation of inventory results such as analysis of percent change in GHGs.

This section includes a detailed discussion of each of these steps. A worksheet to assist in the inventory process can be found in Appendix A or downloaded from http://www.tufts.edu/tci.

Defining the Goal and Scope

It is important to begin with a clear and concise documented goal and scope for the inventory. Two key questions to ask in determining the goal and scope of the inventory are:

- What will be the use of the inventory information?
- Who is the target audience?

Addressing these questions at the onset of the effort, will facilitate the authorship and contribution of a useful inventory. For example, the inventory may be used for a benchmark that is then to be compared to inventories for future years. Careful documentation of what was included in the benchmark will be important for the comparative assessment to future emission inventories. Further, additional information, such as the timing of changes in capital equipment may also be useful to track reduction implementation efforts.

Additionally, the goal and scope of the inventory should be defined to specify:

- the boundary of operations/activities,
- the associated GHG emissions of these activities, and
- the metrics of measurement.

Determining the Inventory Scope

A properly defined goal and scope then facilitates the definition of the operational boundary or the universe of emission sources to be identified. The goal and scope will determine the extent of this boundary. For example, an inventory could consist of only those activities controllable within the confines of the university campus or what is known as a "gate-to-gate" analysis. This would include all of the direct emission associated with the university.

1. Direct emissions are those emissions that occur from activities owned wholly or in part by the university. These include the combustion of fossil fuels for heating, maintenance activities and transportation of students and staff for university activities. Other direct contributions of emissions of GHGs include laboratory activities, on-site composting, methane emissions from domesticated animal solid waste and enteric fermentation, and the intra-campus transport of materials.

Typically, GHG inventories include a "gate-to-gate" analysis with the additional indirect sources of emissions due to energy use in the form of electricity or steam. This type of hybrid analysis is basically one level upstream-to-gate. It is not a true one level upstream analysis in the sense that all other activities beside electricity and steam generation, such as the GHGs associated with the production of heating fuels, are not included in the analysis.

2. Indirect sources of GHG emissions are releases from sources not owned by the university but occur as a result of university activities, such as the manufacture of goods. Other major indirect emission releases associated with university activities include the commuting population of staff and students. Indirect emissions are typically not included in an inventory due to inaccessibility of data and costs of collection. Major indirect emission releases not included are those associated with new construction and renovations of buildings and infrastructure.

3. The most comprehensive of inventories would include a "cradle-to-grave" analysis. This would include all of the GHGs associated with not only combusting fossil fuels on campus but all indirect activities associated with both upstream and downstream from the university. For example, the **other indirect sources of GHG emission** releases associated with all materials entering and leaving the university, such as the production, transport, and final disposition (reuse, recycle, or disposal) of desk, chairs, computers, and paper. The indirect emission releases from both sources can be a significant percentage of total emissions.

In addition to determining the extent of activities to include in the inventory, one must also determine which GHGs to include in the inventory. The major GHG emission by most universities, both on a mass basis and a global warming potential (GWP) basis is CO_2. It is recommended that activities associated with the emission of CO_2 should be considered first. Other GHGs, such as methane and nitrous oxide can contribute significantly based on their GWP. For example, methane on a mass basis is twenty-one times more likely to contribute to global warming than CO_2. Therefore, even small potential sources of these non-CO_2 GHGs should be investigated as a minimum based on their potential contribution.

Measurement Metrics

Once the breadth and depth of the inventory has been determined, one must also define the measurement metric or functional unit of the inventory. At first glance, the definition of the boundary for the inventory may appear to be trivial. However, careful thought regarding the balance of practical limitations of data collection and the purpose of the inventory at the onset will facilitate the completion of a successful inventory, providing important baseline information and transparency to the sources of emissions. The definition of measurement metrics will allow for trend analysis at the university level.

Key parameters are units for quantities tabulated and the interval of time considered for the inventory. The heat-trapping ability of one metric ton (1,000 kilograms) of CO2 is taken as the standard, and emissions may be expressed in terms of metric tons of CO2 equivalent (MTCDE). More typically units are quantities tabulated in an amount in both short tons and million metric tonnes of carbon equivalents (MMTCE) based on the activities of a university for the duration of one year. To arrive at MMTCE, the weight of the carbon dioxide gas is multiplied by it's global warming potential, and multiplied again by 12/44. By weight, carbon is 12/44 of carbon dioxide. The weight of gas is calculated in grams, and one teragram (Tg) equals a million metric tons. (*International Carbon Bank & Exchange*, http://www.icbe.com/emissions/mmtce.asp)

$$\textbf{MMTCE = (Tg of gas) x (GWP) x (12/44)}$$

Table 1. Mass Conversion Factors

To:	**kg**	**t**	**lt**	**st**	**lb**
From:	**multiply by:**	.	.	.	.
kilogram (kg)	1	0.001	9.84 x 10^{-4}	1.102 x 10^{-3}	2.2046
tonne (t)	1000	1	0.984	1.1023	2204.6
long ton (lt)	1016	1.016	1	1.120	2240.0
short ton (lt)	907.2	0.9072	0.893	1	2000.0
pound (lb)	0.454	4.54 x 10^{-4}	4.46 x 10^{-4}	5.0 x 10^{-4}	1

Source: International Energy Agency Units and Conversion Factors.http://www.iea.org/stats/files/units.htm

Other functional unit parameters can also be determined for purposes of detailed analysis and comparative assessment by similar institutions. These include the following:

- Number of enrolled students on a full-time equivalent (FTE) basis (frequency)/ total emissions (MTCE). Typically a part-time student is equal to 1/2 full-time student.

- Total facility floor space (sq. ft.) / total emission (MTCE). The total facility floor will be used to estimate a level of efficiency as Tufts completes new construction and renovations.

Data Gathering - Categories, Units, and Conversion Factors

At the university entity level, the predominant source of GHGs is CO_2, both directly and indirectly from the use of fossil fuels. The following is a summary of the direct and indirect emissions data categories Tufts University collected for our GHG inventory. (See summary Table 4.) The inventory template used by Tufts University can be found in Appendix A, or downloaded from http://www

<u>Direct Emissions</u>

Direct emissions are those emissions that occur from activities owned wholly or in part by a university. These include CO_2 emissions from the combustion of fossil fuels for heating, maintenance activities, transportation of students and staff for university activities, and the intra-campus transportation of materials.

Other direct contributions of emissions of GHGs include non-CO_2 emissions from laboratory activities and on-site composting methane emissions, from domesticated animal solid waste and enteric fermentation. The significant emissions of non-CO_2 GHGs included in the Tufts University inventory include methane (CH_4) from domesticated animals and nitrous oxide (N_2O) emissions from the Dental School. Other non-CO_2 GHGs such as halons, carbon tetrachloride, methyl chloroform, HCFCs and CFCs (contained within refrigeration equipment) are also present but are assumed to be contained and in extremely small quantities and therefore are not included in this inventory methodology.

The majority of the sources for direct CO_2 emissions data are from combustion of fuels. These include the release of CO_2 from the combustion of natural gas, Type 2 fuel oil, Type 6 fuel oil, propane, motor gasoline, and diesel fuel.

Typically, the facilities, or operations department of a university maintains campus meter readings and delivery records for each of the fuels. It is important to note that information for some fuels, especially for those purchased in bulk, may be difficult to obtain on a calendar year basis. This may be particularly troublesome for the year 2000, whereby stockpiling may have occurred in the previous year (FY 1999) to avert any potential Y2K. Records are typically kept on a fiscal year basis, and may need to be estimated for use during the calendar year.

A short discussion of each fuel is as follows:
Natural gas - is used for space and water heating, as well as for cooking in kitchens. It is used in both large and small buildings throughout a campus. Natural gas is typically measured in hundreds of cubic feet (Ccf), but is also measures in dekatherms or million Btus and is generally recorded monthly. Conversion of natural gas to pounds of CO_2 is 12.06 lbs. CO_2/Ccf (EIA 1999).

Table 2. Natural Gas Conversion Factors

Multiply	By	To Obtain
British Thermal Units	$(\_\text{Btu per cf})^{-1}$	cubic feet
cubic feet	7.481	gallons (U.S.)
cubic meters	35.31	cubic feet
dekatherms	$10^6(\_\text{Btu per cf})^{-1}$	cubic feet

Source: "Metric Unit (SI) Application Guide" (A.G.A. Catalog No.X50980).
http://www.aga.org/glossary/conversion.html

Type 2 Fuel Oil - also known as #2 fuel oil or distillate fuel is used in some individual buildings and at central heating locations on a campus. Type 2 fuel oil is typically purchased from local distributors and delivered on an as-needed basis in units of gallons. Conversion of Type 2 fuel oil to pounds of CO_2 is 26.03lbs. CO_2/gal. (EIA 1999).

Type 6 Fuel Oil - also known as #6 fuel oil or residual fuel is used at central heating locations on a campus. Type 6 fuel oil is delivered in bulk form several months before use. Therefore, discrepancies due to stockpiling can cause errors of estimated use. Type 6 fuel purchased are measured in barrels and can be converted to gallons with the conversion factor: 1 barrel = 42 gallons. Conversion of Type 6 fuel oil to pounds of CO_2 is 22.38lbs. CO_2/gal. (EIA 1999).

Propane - is used for heating, kitchen and laboratory purposes and is typically present in more rural locations. Propane is purchased on an as-needed basis in units of gallons. Conversion of propane to pounds of CO_2 is 12.67lbs CO_2/gal. (EIA 1999).

Gasoline - purchases are separated into purchases for the university fleet and for commuter use. Purchases of gasoline for a university fleet may be present in bulk form or by individual purchases. Gasoline purchased in bulk form will typically be recorded by the facilities department and provided by local supplier to accommodate the police department, mail delivery, maintenance truck fleet, athletic vans and various landscaping equipment. Gasoline purchased individually will be in the form of potentially hundreds of separate purchases at several retail gasoline distributors. Gasoline fuel is typically purchased by the gallon.

Estimated gasoline purchases and subsequent emission releases attributed to commuter fuel consumption can be estimated by surveys of commuter behavior. For example, a survey conducted by Tufts University found that approximately 2000 personnel commuters at a 75% single occupancy rate. This equated to 1750 vehicles with a surveyed average trip distance of 27 miles (Edmondson and Creighton 1992). The average fuel economy in 1990 was 20.2 miles per gallon (BTS 1999). Commuter fuel use calculations were then based on 150 commuter days (two 15 week semesters). It is likely that this example underestimates the actual fuel use. Additional information such as estimating the percentage of passenger vehicles, light-trucks and minivans used and a more accurate average of number of days commuting by staff and faculty.

Conversion of gasoline to pounds of CO_2 is 19.59 lbs. CO_2/gal. (EIA 1999).

Diesel Fuel - similar to gasoline, diesel fuel purchases may be done in bulk or by individual purchases for the university fleet. Diesel fuel is also known as distillate fuel and has the same carbon content as Type 2 fuel oil. Diesel fuel is typically purchased by the gallon. Conversion of diesel to pounds of CO_2 is 22.38 lbs. CO_2/gal. (EIA 1999).

Table 3. Common Fuel Units

To:	**gal U.S.**	**bbl**	**ft^3**
From:	**multiply by:**	.	.
U.S. gallon (gal)	1	0.02381	0.1337
Barrel (bbl)	42.0	1	5.615
Cubic foot (ft^3)	7.48	0.1781	1

Source: International Energy Agency Units and Conversion Factors.http://www.iea.org/stats/files/units.htm

Indirect Emissions

Indirect emission releases are emissions attributed to those sources not owned by the University but occur based on activities initiated by the university. At this time, there is only one CO_2 category included in the inventory for indirect emission releases. The category is the secondary upstream emissions by electricity use.

Electricity - is measured in kilowatt-hours (kWh). Conversion of electricity to pounds of CO_2 differs based on fuel input. Emission coefficients by state level for the years 1997 through 1999 can be found at: (USDOE EIA, 2001b), on the web: http://www.eia.doe.gov/oiaf/1605/e-factor.html

These state-level electricity emissions factors represent average emissions per kWh or MWH generated by electric utilities for the 1997-1999 time period. They do not include emissions from power produced by non-utility generators. The Voluntary Reporting of Greenhouse Gases Program believes these factors provide reasonably accurate default values for power generated in a given state. However, reporters should use these state-level factors only if utility-specific or power pool-specific emission factors are not available.

Other Indirect Emissions

Additional major sources of indirect emissions include steam use, the emissions released from the construction of new campus facilities and emissions related to the production of all material goods purchased by a university. These indirect contributions to these emissions are difficult to obtain with accuracy and are not included in this inventory guideline.

Cautions in Data Gathering

In gathering data for an inventory it is important to be cautious of how fuel use quantities are derived. For example, at Tufts University some fuels are purchased in bulk on an as needed basis that results in a lag between purchasing and use. In particular, Type 6 fuel oil was stockpiled in 1999 to safeguard against shortages as a result of potential Y2K problems. Basing inventory data on billing rather than use records would have incorrectly led to increased emissions based on purchases in 1999 and subsequently reduced emission results for the year 2000.

Another caution in using billing data to estimate fuel use, is that bills (especially natural gas) may estimate monthly or quarterly use and adjust for actual metered use in subsequent billing periods. Thus it is important to understand how different data is collected and reported in order to select the source that most accurately reports actual fuel usage from which reliable emissions data can be calculated.

Table 4. Summary of data categories, units, and conversion factors (DOE EIA, 2001b).

Direct Emissions (emissions released based on activities by the University)	**CO_2 lbs./volume or mass**	**N_2O lbs./volume or mass**	**CH_4 lbs./volume or mass**
Natural Gas	12.059 lbs./ hundred cubic feet (Ccf)	0	0
#2 Oil	22.384 lbs./ gal.	0	0
#6 Oil	26.033 lbs./ gal.	0	0
Propane	12.669 lbs./ gal.	0	0
Gasoline use by University Fleet (Delivery, landscaping, waste management, police, fire, shuttle)	19.564 lbs./ gal.	0	0
Gasoline use by Commuters (cars & vanpools)	19.564 lbs./ gal.	0	0.
Diesel	22.384 lbs./ gal.	0	0
Indirect emissions (emissions released based on sources not owned by the University)			
Electricity - emission varies by fuel input estimates available at state level (DOE EIA, 2001a) Example- Massachusetts	1.236 lbs./ kWh	0.0167 lbs./ MWh	0.0076 lbs./ MWh

Global Warming Potential (GWP)

In general to generate a concise inventory of GHGs, one must compare radiative forcing for each of the specific gases and their respective atmospheric lifetime. These two factors combined are the basis of the computation for the global warming potential (GWP) of a GHG. The radiative forcing of a gas is the amount of reduction in infrared radiation leaving Earth per unit increase in atmospheric abundance. The atmospheric lifetime is the average amount of time a gas is present in the atmosphere after release. For example the atmospheric lifetime of CO_2 is in the order of 100 years. The GWP for all GHGs are then normalized to the GWP of CO_2. A summary of the most prevalent GHGs and their respective GWPs are presented in Table 2.

Table 5. Summary of GWP for the most prevalent GHGs.

Gas	**Lifetime (Years)**	**GWP for a time horizon of 100 years**
Carbon Dioxide (CO_2) *Fossil fuel burning*	Variable (~100 years)	1
Methane (CH_4) *Domesticated Animals, Waste management*	12 ± 3	21
Nitrous Oxide (N_2O) *Medicinal Uses*	120	310
HFC-23 *Refrigeration*	264	12,100
HFC-125 *Refrigeration*	33	3,200
HFC-134a *Refrigeration*	15	1,300
HFC-152a *Refrigeration*	2	140
HFC-227ea *Refrigeration*	37	2,900
Perfluoromethane (CF_4) *Aluminum production*	50,000	6,500
Perfluoroethane (C_2F_6) *Aluminum production*	10,000	9,200
Sulfur Hexafluoride (SF_6) *Various Industrial Processes*	3,200	23,900

Source: Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996), p. 121.

Interpreting Inventory Results

The goal of the inventory is to develop a baseline, see trends and measure future progress. Some uncertainty will always arise in the data collection process due to human error, lack of standard or infrequent reporting across departments, and estimation to compensate for missing data.

The methodology outlined here for completing a GHG emissions inventory provides a quick and inexpensive way to documenting an institution's emissions sources. This broad-brush approach will be most useful in identifying emissions trends and areas of growth, suggesting spheres of influence and activities where emissions reductions and increase energy efficiency increases can have the greatest impact. It will also aid in revealing whether an institution is becoming more energy intensive through energy increases that occur not only on a university-wide basis, but also on a per student and per facility square foot basis. However an inventory does not, by itself, inform what and where to act.

What we found - what worked and what didn't.

The GHG emissions inventory for Tufts University indicated an upward trend in the emission release levels. From this preliminary inventory, notable observations included an overall increasing trend of energy use - especially electricity plug loads from the quantity and subsequent use patterns of personal computers by students. This increase will be particularly difficult to reduce in order to meet the goals put forth by the Kyoto Protocol by 2010. Moreover, energy increases are not only on a university-wide basis but also on a per student and per facility square foot basis. Essentially, the university is becoming more energy intensive, both on net and by normalized metrics.

The majority of the data collected were related to direct emissions from fuel use, and indirect emissions one level upstream for electricity and steam energy purchases. In general, access to the fuel purchasing data allowed for a quick inventory of the major sources of direct GHG emissions. Indirect emissions data, such as estimates of transportation fuel use; materials purchasing, consumption and end disposition; new construction; and facility renovations were more difficult to obtain. The difficulties are due in part from the lack of data as well as the labor requirements and expense of an expanded boundary for data collection. These categories still represent potentially more than 30-35% of overall GHG emissions. (*Gloria, 2001.*)

Data regarding the amount of fuel required to deliver a pound of steam was also not readily available. The quantity steam generated or purchased is a substantial source of CO_2 emissions. It is the second single largest source after electricity. Tufts University's Boston campus purchases steam from TRIGEN, Inc. TRIGEN estimates a maximum of 90% efficiency based on the co-production of three energy products - electricity, steam and chilling water. Further information to refine this conversion factor would require allocation of energy production requirements based on a Btu content basis of the energy product delivered. In order to gain a better understanding of the amount of energy to deliver a pound of steam further information regarding the efficiency of the other two products is necessary. At this time, a range of 30% to 60% efficiency is possible. Refining the parameter of efficiency is a high priority.

Calculations of emissions based on electricity purchases also did not compensate for marginal changes, rather a single intensity factor was used for all levels of consumption. Typically, power plant technologies, such as nuclear facilities operate at optimal levels of electricity production. As demand shifts, other fuel sources, such as oil and coil are used with more discretion. Hence, marginal emission reductions would vary from an across the board reduction in fuel use. In many cases the marginal difference may actually be greater than the average. Due to electricity purchases representing more than 50% of the emissions, this marginal difference, could be a significant source of error in the final calculation of emission quantities.

Emissions data categories not in Tufts' inventory that should be included are:

- Direct non-CO_2 GHG emissions from domesticated animals (CH_4), medical uses (N_2O), and refrigeration (HCFCs and CFCs) are currently not included in the inventory. It is assumed that these materials are contained and present in very small quantities. However, based on the GWP of these gases, they represent a potentially large source of GHG emissions.

- Indirect emissions attributed to new construction. Several construction projects have occurred on the Tufts campuses over the past decade that have resulted in an increase of 230,000 square feet.

- Indirect upstream emissions associated with the embodied energy of every material or piece of equipment purchased by the University is currently not included in the inventory. The upstream emissions are those emissions embodied with production and distribution of products. For example, the embodied energy in construction materials in the Vancouver, BC has been shown to be comparable to 9-12 years of operational energy use (Norris 1998)(Cole 1993).

- Indirect downstream emissions due to releases from solid waste end-of-life disposition activities such as re-use, recycling and disposal (the use phase is captured by energy and fuel purchases). Tufts University has a 33% recycling rate (Creighton 1998, 56). At this level of recycling it is estimated that a reduction of approximately 300 MTCE could be achieved per year (USEPA, 1999). This is equivalent to approximately 5% of the current total reduction necessary to achieve the 2012 goal at 1998 levels.

As more information becomes available, coefficients of emission releases based on embodied energy quantities will be developed. In the future, we hope to expand our emissions inventory methodologies to accurately and affordably include the embodied energy content of the materials and equipment - including new construction and renovations of facilities. This expansion of the inventory will capture a larger portion of the indirect emissions attributed to the purchasing choices by Tufts' staff, faculty and students. By capturing the broadest boundary of influence by a university, appropriate choices for action will be better realized.

Appendix A:

Greenhouse Gas Emissions Inventory Template

Acronyms

BTS	- Bureau of Transportation Statistics
Btu	- British thermal unit
CFCs	- chlorofluorocarbons
CH_4	- methane
CO_2	- carbon dioxide
FTE	- full-time equivalent student
GHG	- green house gas
GWP	- global warming potential
HCFCs	- hydrochlorofluorocarbons
kWh	- kilo-watt-hours
LCA	- Life-cycle Assessment
MMBtu	- one million British thermal units
MTCE	- metric tons carbon equivalent
MMTCE	- million metric tons carbon equivalent
MT	- metric ton
MWH	- mega-watt hours
N_2O	- nitrous oxide
USEPA	- United States Environmental Protection Agency
Y2K	- year 2000

Glossary

Metric tonne of carbon equivalent (MTCE) - Carbon comprises 12/44 of the mass of carbon dioxide; thus to convert from CO2 equivalent to C equivalent, one multiplies by 12/44.

British thermal unit (Btu) - The quantity of heat required to raise the temperature of one pound of water from 60° to 61°F at a constant pressure of one atmosphere.

metric ton - A unit of mass equal to 1,000 kilograms (2,205 pounds).

short ton - see ton

stressor - an object or an action that has potential environmental repercussions.

ton - A unit of weight equal to 2,000 pounds (0.907 metric ton or 907.18 kilograms). Also called *net ton, short ton.*

tonne - A metric ton

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Additional information on climate change and greenhouse gases can be found at the following websites:

Tufts Climate Initiative at the Tufts Institute of the Environment: http://www.tufts.edu/tie/tci/

United Nations Environmental Program site:

http://www.grida.no/climate/vital/index.htm

US EPA:
http://www.epa.gov/globalwarming/

Energy Information Administration - Introduction to Greenhouse Gases, Global Climate Change and Energy:
http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html

Further information about Global Warming Potentials can be found at:

Energy Information Administration
http://www.eia.doe.gov/oiaf/1605/ggrpt/tbl3.html

US EPA site for ozone depleting substitutes:
http://www.epa.gov/ozone/geninfo/gwps.html

Other structured inventory approaches can be found at the following web sites:

US Department of Energy (DOE) - voluntary reporting program.
http://www.eia.doe.gov/oiaf/1605/frntvrgg.html

International Council for Local Environmental Initiatives (ICLEI).
http://iclei.org/co2/

New Jersey Higher Education Partnership for Sustainability (NJHEPS)
http://www.njheps.org

GHG Protocol Initiative
http://www.ghgprotocol.org/standard/ghg.pdf

International web sources:

http://www.unfccc.de
United Nations Framework Convention on Climate Change: The United Nations site on the climate change treaty negotiations.

http://www.unfccc.de/resource/beginner.html
Understanding Climate Change: A Beginner's Guide to the United Nations Framework Convention.

http://www.unfccc.de/resource/convkp.html
Extensive information about the United Nations Convention on Climate Change and the Kyoto protocol.

http://www.unfccc.de/resource/docs/convkp/kpeng.html
Has the full text of the Kyoto protocol

http://www.ipcc.ch
Intergovernmental Panel on Climate Change Site: Official site of the IPCC, a body of more than 2,000 scientists sponsored by and reporting to the United Nations.

University and College web sources:

National Wildlife Federation Campus Ecology
http://www.nwf.org/campusecology/index.html

New Jersey Higher Education Partnership for Sustainability http://www.njheps.org

Princeton University http://www.princeton.edu/~perc/

Brown University http://www.brown.edu/Departments/Brown_Is_Green/

University of Vermont http://esf.uvm.edu/envcncl/

Middlebury College http://www.middlebury.edu/%7Eenviroc/

University of Buffalo http://wings.buffalo.edu/services/recycling/

US Government web sources:

US Department of Energy

Voluntary Reporting of Greenhouse Gases Program:
http://www.eia.doe.gov/oiaf/1605/frntvrgg.html

Emission conversion factors:
http://www.eia.doe.gov/oiaf/1605/factors.html

Emission of Green House Gases in the US 2000
http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html

Introduction to Green House Gases, Global Climate Change and Energy
http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html

Argonne National Laboratory - Transportation Technology R & D Center
Emissions related to transportation
http://www.transportation.anl.gov/ttrdc/greet/index.html

US Environmental Protection Agency

EnergyStar
http://www.energystar.gov

Research on GHG contribution from solid waste:
http://www.epa.gov/epaoswer/non-hw/muncpl/ghg.htm

US Global Change Resource Program
http://www.usgcrp.gov/