

INEEL/EXT-99-00986
Revision 0

INEEL Greenhouse Gas Inventory and Trend Analysis

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February 2000



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**Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727**

Acknowledgments

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Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727

Table of Contents

Acknowledgments	1
Table of Contents	2
List of Figures and Tables	4
Executive Summary	5
I. Study Overview	6
Climate Change Problem	6
INEEL Global Climate Change Program	7
Study Objectives	8
Reference Methodologies	8
INEEL Greenhouse Gas Inventory System Description	9
Report Organization	9
II. Energy Usage at the INEEL	10
Facilities	10
Transportation	10
Energy Use Methodology	10
Thermal Energy Use Information	11
III. Greenhouse Gas Calculations	13
Energy Calculations	13
Waste Calculations	14
IV. Other Greenhouse Gas Generation Sectors	16
Industrial	16
Solvents	16
Agriculture	17
Land Use	17
V. INEEL Greenhouse gas inventory and trend analysis	18
INEEL 2010 GHG Reduction Target	20
Verification of Results	20
Uncertainty Analysis	20
VI. Conclusions	21
Summary Results	21
Future Actions	21
References	22

Appendix Report

(Separate Document)

INEEL Gas Inventory and Trend Analysis Supporting Data and Calculations

List of Figures and Tables

INEEL GHG Inventory 1990-1998.....	5
Figure 1: Atmospheric CO ₂ Levels.....	6
Table 1: Greenhouse Gases and Sources	6
Table 2: Photochemically Important Gases and Sources	6
Figure 2: CO ₂ Levels and Temperature Change.....	7
Figure 3: INEEL Annual Thermal Energy Use by User	11
Figure 4: INEEL 1990 Thermal Energy Use	11
Figure 5: INEEL Annual Thermal Energy Use by Energy Source	11
Figure 6: 1990 Thermal Energy Use by Energy Source	11
Figure 7: INEEL Annual Electricity Use by Generation Source.....	12
Figure 8: INEEL Annual Thermal Electricity Use by User	12
Table 3: 1990 INEEL Greenhouse Gas Emissions by Source/Gas	18
Figure 9: Annual Greenhouse Gas Emissions for All Gases by Source	19
Figure 10: INEEL 1990 Greenhouse Gas Emissions (CDE) for All Sources by Gas Type.....	19
Figure 11: Annual Non-CO ₂ Emission by Source	19
Figure 12: Annual Emissions (Excluding CO ₂) for Facilities, Transportation and Waste.....	19
Figure 13: Targeted 2010 GHG reduction goals	20

Executive Summary

The objective of the INEEL GHG Inventory and Trend Analysis is to establish INEEL expertise in carbon management decision making and policy analysis. This FY-99 effort is the first step toward placing the INEEL in a leadership role within the DOE laboratories to support carbon management systems and analysis.

The overwhelming reliance on fossil energy to fuel the economy is increasing the atmospheric levels of greenhouse gases, particularly the build-up of carbon dioxide (CO₂). The anthropomorphic impacts of CO₂ are now exceeding the natural systems' equilibrium. Climate related problems are becoming commonplace (e.g., droughts, increasing ocean levels, floods, reduced agriculture production, and pest infestations). The response to the growing concern about greenhouse gases (GHG) includes:

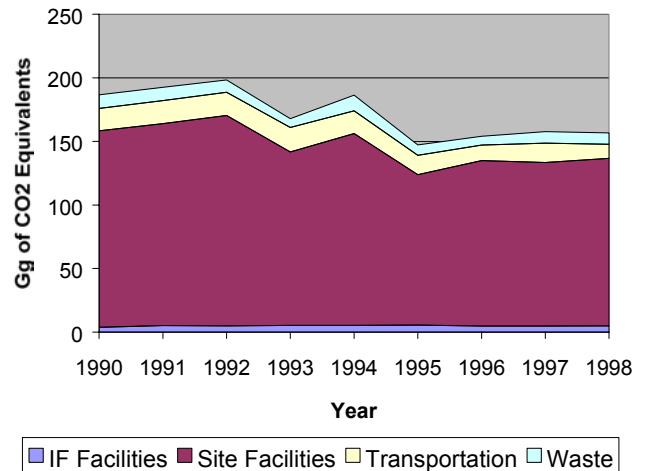
- Signing of the United Nations Framework Convention on Climate Change in Rio de Janeiro in June 1992.
- Becoming a signatory to the Kyoto Protocol in 1997, requiring reduction of carbon emissions to 7% below 1990 levels.¹
- The President's Executive Order (E.O. #13123) in June 1999, requiring federal facilities to reduce GHG emissions by 30% (of 1990 level) by 2010.

The INEEL GHG inventory is a preliminary study to meet the intent of E.O. #13123.² This analysis includes an accounting of the GHG emissions from INEEL facilities, transportation, and waste operations. The analysis provides a GHG baseline for 1990 and emission trends from 1991-1998. The annual INEEL GHG emissions are presented in the INEEL GHG Inventory 1990-1998 figure.

A summary of the major conclusions from the INEEL Greenhouse Gas Inventory and Trend Analysis are provided in the following bullets.

¹ The commitment will not be officially assumed unless the U.S. Senate ratifies the Kyoto Protocol.
² The DOE is expected to issue a DOE Order by June 2000 to implement E.O. # 13123. The DOE Order may require changes to the estimated INEEL 1990 inventory baseline and related emission reduction goals for 2010.

INEEL GHG Inventory 1990-1998



- The total INEEL Greenhouse Gas inventory for 1990 is 186.6 Gg (in CO₂ equivalents).
- GHG generation has ranged from 106% (1992) to 79% (1995) of the 1990 baseline.
- Carbon Dioxide (CO₂) at 92% and Methane (CH₄) at 6% are the primary greenhouse gas contributors at the INEEL.
- Facilities (88%), followed by transportation (12%) are the largest INEEL fuel users that contribute to greenhouse gas generation.
- Total energy usage has held fairly constant from 1990-1997. Thermal energy use has declined by about 15%.
- INEEL greenhouse gas emission levels are significantly affected by the availability of energy from hydropower, which is affected annually by precipitation levels.
- A INEEL GHG Mitigation and Action Plan is needed to achieve the emission reduction goal of 130.7 Gg (CO₂ equivalent), to meet the 30% reduction goal from the 1990 level.

Future steps include:

- 1) Preparation of a detailed analysis of the INEEL GHG inventory – incorporating the DOE implementation guidance.
- 2) Developing INEEL GHG mitigation and action plans to meet the 2010 emission goals.
- 3) Developing unique systems capabilities to support carbon emissions offset certification and monitoring and verification.
- 4) Developing carbon-trading systems.
- 5) Advancing the science and technology in climate change.

I. Study Overview

Section I provides an overview of the climate change problem, the major GHG sources, the objectives of this analysis, methodology, and supporting program activities.

Climate Change Problem

The overwhelming reliance on fossil energy to fuel the economy – electrical generation, transportation and industrial production – is increasing the atmospheric levels of greenhouse gases, e.g., carbon dioxide (Figure 1).

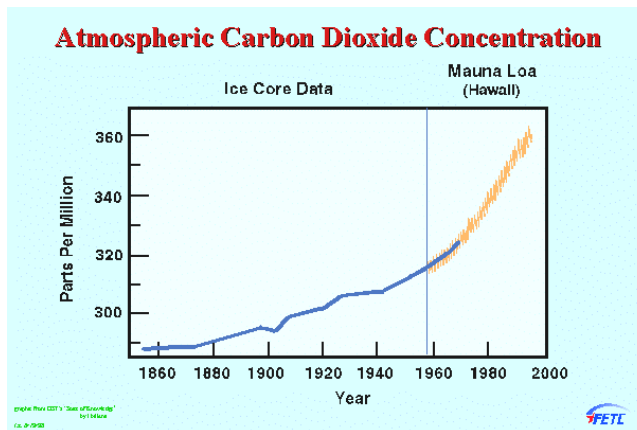


Figure 1: Atmospheric CO₂ Levels

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). Some human-made compounds – including chlorofluorocarbons (CFCs), partially halogenated fluorocarbons (HFCs), and perfluorinated carbons (PFCs) – are also greenhouse gases. The greenhouse gases are listed along with their major sources in Table 1.

There are also photochemically important gases such as carbon monoxide (CO), oxides of nitrogen (NO_x) and nonmethane volatile organic compounds (NMVOCs). These gases are not technically greenhouse gases, but contribute indirectly to the greenhouse effect by influencing the rate at which ozone and other greenhouse gases are created and destroyed in the atmosphere. Emissions of the photochemical gases, known as criteria pollutants, are regulated under the Clean Air Act of 1970 and subsequent amendments.

Greenhouse Gases	Major Sources
Carbon Dioxide (CO ₂)	Combustion of liquid, solid, and gaseous fossil fuels
Methane (CH ₄)	Production, transportation of coal & natural gas; and anaerobic decomposition of organic matter
Halogenated Fluorocarbons (HFC's and PFC's)	Aerosol additives, Aluminum production, refrigerants
Nitrous Oxide (N ₂ O)	Fertilizers, fossil fuel combustion
Ozone (O ₃)	CFC's

Table 1: Greenhouse Gases and Sources

The photochemically important gases are listed along with their major sources in Table 2.

Photochemically Important Gases	Major Sources
Carbon Monoxide (CO)	Incomplete combustion of carbon fuels
Oxides of Nitrogen	Lightning, Biomass burning, fossil fuel combustion
Nonmethane VOC's	Transportation, industrial processes, forest fires, organic solvents

Table 2: Photochemically Important Gases and Sources

The anthropomorphic impacts of CO₂ exceed the natural systems' equilibrium. Climate related problems are becoming commonplace (e.g., droughts, increasing ocean levels, floods, reduced agriculture production, and pest infestations). Figure 2 reflects one aspect of the climate change disequilibrium – the increasing atmospheric temperature. While there is debate about the symptoms of the problem, there is consensus that the “do nothing” option is not viable and there is no single “quick fix” that provides an affordable, technically feasible alternative to relying on fossil energy.

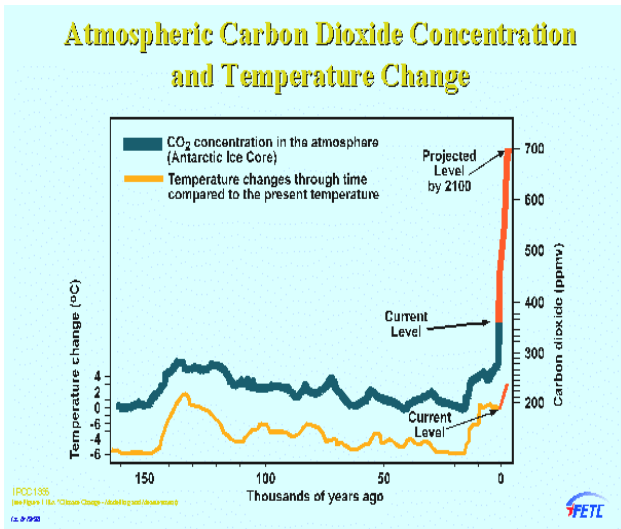


Figure 2: CO₂ Levels and Temperature Change

History

Signature of the United Nations Framework Convention on Climate Change in Rio de Janeiro in June 1992 indicated a widespread recognition that climate change is potentially a major threat to the world’s environment and economic development. The convention included a legal framework for voluntary reductions of greenhouse gases (GHG), or other actions such as enhancing GHG sinks, aimed at stabilizing atmospheric concentrations of GHG to 1990 levels. In October 1992, the U.S. became the first industrialized nation to ratify the treaty.

In 1997, the U.S. became a signatory to the Kyoto Protocol, thereby assuming a potential commitment to implement the policies required to reduce the nation’s carbon emissions to a level that is 7% below 1990 levels. (The commitment will not be officially assumed unless the U.S. Senate ratifies the Kyoto Protocol.) In continuing international negotiations associated with the Kyoto Protocol, the official U.S. position is to require “flexible mechanisms” for implementing the agreement, by which are meant emissions trading and joint implementation.

In an Executive Order signed by President Clinton in June 1999, federal agencies, including the Department of Energy, will be required to meet new energy efficiency and greenhouse-gas-

emission reduction goals. The President’s Executive Order #13123 (E.O.# 13123), *Greening the Government Through Efficient Energy Management*, mandates federal facilities to reduce GHG emissions by 30% of 1990 level by 2010. This order, which has been driven by Clinton/Gore, is consistent with the current administration policies toward the United States ratification of the Kyoto treaty.

E.O.# 13123 serves as a catalyst to set off a chain reaction of activities within the federal facilities to meet this new requirement. Although the Department of Energy has not issued the implementing guidance of E.O. #13123, the INEEL anticipates that the DOE laboratories will be required to establish a 1990 energy usage and GHG baseline and set emission reduction targets for 2010. The process and mechanisms needed to perform an energy baseline are well established, but the widespread accounting and mitigation of GHG (primarily CO₂ and methane) is unprecedented within the DOE system. The INEEL is in a position to take a leadership role within the DOE laboratories to support the implementation of this DOE order.

This history serves to show an emerging national need to support the evolution of robust domestic and international carbon emissions trading regimes. Initially, it will be necessary to build the institutional capacity to provide certification protocols for emissions credits from multiple project sources. Such protocols will in turn provide the required technical support for the private markets that will engage in trading this latest “commodity.” The protocols will have to address the basic elements of carbon emissions offset certification: a reliable project baseline analysis, as well as ongoing monitoring and verification of project emissions.

INEEL Global Climate Change Program

The INEEL Global Climate Change (GCC) Program has sponsored the INEEL Greenhouse Gas Inventory and Trend Analysis, which, to the best of our knowledge, is the first, such analysis performed on a DOE-operated multipurpose facility. In carrying out this exercise, the laboratory has built in-house expertise, as well as many of the systems and models required to analyze carbon emissions baselines and to carry

out ongoing emissions monitoring and verification.

The initial mission of the GCC Program will be to take the first steps required to position the laboratory to capture this emerging opportunity which, if it does materialize, could support what has the potential to become the largest single commodity market in the world. In so doing, the laboratory will be serving a national need by helping to make possible the carbon emissions trading market required to efficiently implement our commitment to reduce carbon emissions.

The GCC Program expectation is that this initial small step will lead progressively to larger carbon emissions projects for customers such as the State of Idaho, the DOE system, and other government agencies. It is probably too early to expect to attract corporate customers, but even they might develop in the future if the policy process to implement the Kyoto Protocol moves forward. If a carbon emissions trading regime does develop over the next decade, the INEEL – which has no vested interest in the commercial market actors -- will be well positioned to provide “honest broker” technical support services to the carbon emissions certification market.

Study Objectives

The objective of the INEEL GHG Inventory and Trend Analysis is to establish INEEL expertise in carbon management decision making and policy analysis. This FY-99 effort is the first step toward placing the INEEL in a leadership role within the DOE laboratories to support carbon management systems and analysis.

Future steps include:

- 1) Preparation of a detailed analysis of the INEEL GHG inventory – incorporating the DOE implementation guidance.
- 2) Developing INEEL GHG mitigation and action plans to meet the 2010 emission goals.
- 3) Developing unique systems capabilities to support carbon emissions offset certification and monitoring and verification.
- 4) Developing carbon-trading systems.
- 5) Advancing the science and technology in climate change.

Reference Methodologies

To implement the United Nations Framework Convention on Climate Change, a set of guidelines were established to provide a common framework for calculation and reporting GHG emissions. The Intergovernmental Panel on Climate Change (IPCC) has developed guidelines³ to assist parties in implementation of the climate change accord. These guidelines were developed and approved by an international process consisting of review by national experts, testing of methods through preliminary inventories, country studies, workshops, and expert panels. Although the IPCC guidelines were developed to estimate country GHG inventories, they may also be an aid to federal agencies developing GHG inventories.

The EPA has also developed guidelines and methodologies⁴ for estimating GHG emissions for the development of State-level policies to control emissions. Compiling an inventory of GHG sources and sinks is a critical first step in building a comprehensive and long-range action plan. Subsequent guidance⁵ has been developed by the EPA to provide a framework and supporting information to assist policy makers in further understanding the issues associated with climate change and identifying and evaluating options to mitigate emissions identified in the inventory process. Currently, 34 states have conducted a greenhouse gas inventory.

The State of Idaho has not conducted a GHG inventory.⁶ A rough estimate of the CO₂ emissions (not including CH₄ or other GHG) for the State of Idaho are 3,000 Gigagrams/year for commercial, industrial, residential, and transportation based on 1990-1995 fossil fuel data from the State Energy Data system and DOE’s Energy Information Administration.

³ Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change, 1996.

⁴ US EPA, *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*, EPA 230-B-92-002, November 1992.

⁵ US EPA, *States Guidance Document: Policy Planning To Reduce Greenhouse Gas Emissions*, 2nd Edition, May 1998.

⁶ Based on correspondence with Alan Perrin of the US EPA.

INEEL Greenhouse Gas Inventory System Description

The study includes the operating facilities managed under the Department of Energy Idaho Operations office. Complete listings of the facilities included in this study are provided in Table 1 of the appendix report. Excluded from this inventory are the Argonne-west (ANL-W) facilities that are managed under the DOE-Chicago Operations Office and the Navy Nuclear Training facilities (NRF), which are managed by the Department of Defense under the DOE-Bettis, Pittsburgh Operations Office.

The primary system elements include the Idaho Falls town facilities, the INEEL site facilities, government furnished transportation vehicles, and waste operations. These elements are believed to be the most significant GHG emission sources at the INEEL. Other GHG gas generation sectors are also discussed in Section IV. These sectors include Industrial, Solvents, Agriculture, and Land Use.

Report Organization

This report is organized to address each of the major sectors described in the IPCC guidance report. The major sectors are each addressed along with their contribution to the INEEL greenhouse gas inventory. The major sectors and their locations in the report are as follows:

- Energy (Section III)
- Waste Treatment and Disposition (Section III)
- Industrial Processes (Section IV)
- Solvents and Other Products (Section IV)
- Agricultural Practices (Section IV)
- Land-Use Change and Forestry (Section IV)

Section II provides a description of the INEEL energy use requirements that are used as inputs to the GHG energy calculations.

Section III describes the approach used in calculating GHG inventories for facilities, transportation, and waste.

Section IV describes the non-energy GHG categories including Industrial, Agriculture, Solvents, and Land-Use.

Section V presents the GHG inventories with an explanation of the results and trends, and assessment of areas of uncertainty.

Section VI provides the conclusions from the GHG inventory and trend analysis, and identifies potential actions that could help to reduce the INEEL greenhouse gases to the 2010 target levels.

The INEEL Greenhouse Gas Inventory and Trend Analysis Appendix report includes the detailed backup information for this study.

II. Energy Usage at the INEEL

Section II describes the INEEL energy used as inputs to the GHG emissions calculations. This section explains what energy data is used, what fuels are used to produce energy, and fuel quantities. This section also describes the general methodology for converting the energy data into information used in the GHG emissions calculations (discussed in Section III).

The INEEL is required by DOE Order 430.2 to report energy consumption data on a quarterly basis. Energy usage data is reported for buildings, metered processes, vehicles and equipment. The INEEL report is submitted to DOE-HQ quarterly and is input to the Energy Management System 3 (EMS3) over the Internet.

Facilities

Energy usage data is collected for the INEEL facilities for: 1) Idaho Falls facilities (site #602), and 2) the INEEL site facilities (site # 603). Energy data is collected at a facility level for the Idaho Falls facilities and at areas (e.g., Central Facilities) for site facilities. A list of facilities is provided in Table 1 of the Appendix. Energy use for INEEL site facilities is categorized as metered and non-metered. Metered means that the energy use is measured as it is used and is an energy intensive facility. Non-metered is energy that is not measured directly (e.g., bulk fuel tanks that are filled on an annual basis).

The Idaho Falls (town) facilities use electricity, natural gas, and a small amount of propane in laboratories. The INEEL site uses a much wider variety of fuels. At the site, a great deal of steam is generated using fuel oils (#2 and #5), propane, coal, and trash. Steam is largely used for space heating and some is used in process operations. Natural gas is currently only available as a liquid, which is trucked to the INEEL site.

Information about each of the energy sources and fuels used at the INEEL is provided in Table 2 of the appendix. The information includes standard units of measure; heating values (Btu's per unit); and energy uses (e.g., coal for steam, natural gas for heating office buildings, fuel oil for generators).

Transportation

The transportation energy data is reported with the facilities energy use data on a quarterly basis. The fuels used in transportation include automotive gasoline, diesel, liquid propane, and compressed natural gas.

Various types of vehicles and equipment are used at the INEEL. Table 3 of the appendix report provides annual fleet information including the number of each vehicle type, number of alternative fueled vehicles, and the types of fuels used.

Information about each of the fuels used in transportation is provided in Table 2 of the appendix report. The information includes standard units of measure; energy conversion rates (Btu's per gallon); and energy uses (e.g., diesel for buses, gasoline for light duty vehicles, jet fuel for security helicopters which were used up until 1997).

Energy Use Methodology

The method used to prepare the energy data is consistent with the IPCC and the EPA State guidance. The energy data is developed for input to the GHG calculations by the following steps:

1. Energy data by fuel type, and use (site 602, site 603, vehicles and equipment) is summed for each quarter into a total annual usage.
2. The annual energy data are converted into BTU units by using the conversion factors⁷ provided in Table 2 of the appendix.
3. The BTU energy units are converted to a common energy unit by multiplying the MMBTU's by 1.0547E-03 TJ/MMBTU.
4. The final energy equivalent value (in TJ units) is provided as an input value to the GHG calculations described in Section III.

⁷ **Electricity provided by renewable sources does not emit GHG (e.g., Hydro).** For GHG calculations, the electricity generated from carbon sources (i.e., coal) requires an energy adjustment factor to account for transmission losses from the source to the user facility.

Thermal Energy Use Information

Total INEEL energy usage has held fairly constant from 1990-1997, but the thermal energy usage (not including renewable energy use) has declined since 1990 by approximately 15% (1996-1998). A major reason for the decline is the increased use of hydropower (available due to the high water runoff years). Hydropower has reduced the INEEL's dependence on thermal sources (e.g., coal fired electric utilities). Energy use has also declined due to a reduction in the INEEL workforce from approximately 12,000 to 8,000 employees from 1990 to 1998 (appendix Table 4). Figure 3 shows the annual thermal energy use for Idaho Falls and INEEL site facilities, and transportation.

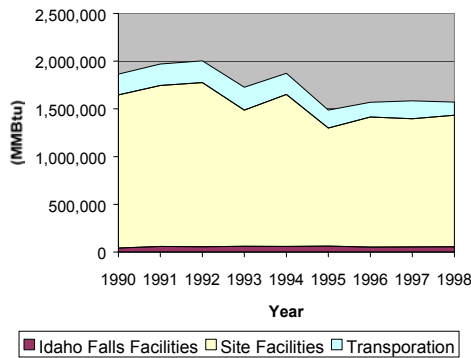


Figure 3: INEEL Annual Thermal Energy Use by User

Figure 4 shows that most of the thermal energy contributing to GHG is from site facilities (86%). Transportation accounts for 12% of the thermal energy, and a small percentage (2%) of the thermal energy is from the Idaho Falls facilities.

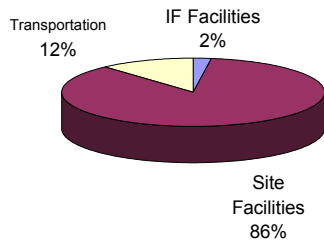


Figure 4: INEEL 1990 Thermal Energy Use

The Idaho Falls facilities receive the majority of their electricity from the city of Idaho Falls. The city of Idaho Falls receives 79% of their electricity from hydropower.

Figures 5 and 6 show the energy breakdown by fuel source. Figure 5 indicates that the mix of fuel types has not changed significantly over time. Figure 6 shows that electricity is the largest INEEL source for thermal energy at 61%. Oil (gasoline, diesel, and fuel oil) and coal are the next highest users at 22% and 14%, respectively. Jet fuel has been a small fuel source and is no longer used at the INEEL.

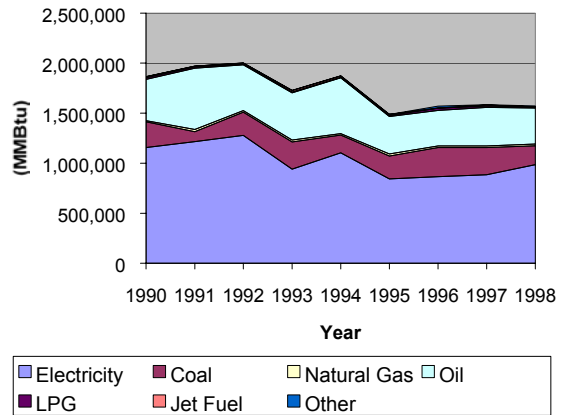


Figure 5: INEEL Annual Thermal Energy Use by Energy Source

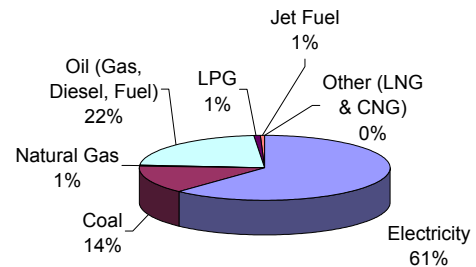


Figure 6: 1990 Thermal Energy Use by Energy Source

The generation source for INEEL electricity has consisted of a mix of hydropower, thermal, and nuclear. The energy mix has changed over time, as shown in Figure 7. The portion of energy (electricity) taken from hydropower has been directly related to the availability of water from annual precipitation. In recent years (1995-1998) the INEEL total energy mix has been approximately 55% hydro powered and 45% thermally powered. The thermal fuel source assumed for this study is coal, based on the proximity of coal burning utilities in the intermountain western United States.

A small percentage of electricity for the INEEL has come from nuclear power sources. The Argonne facility, Experimental Breeder Reactor II (EBR-II) has been an on-site energy source at the INEEL. The EBR II reactor was in operation during the period of 1990-1994. The fraction of energy from EBR-II can be included in future GHG calculations.

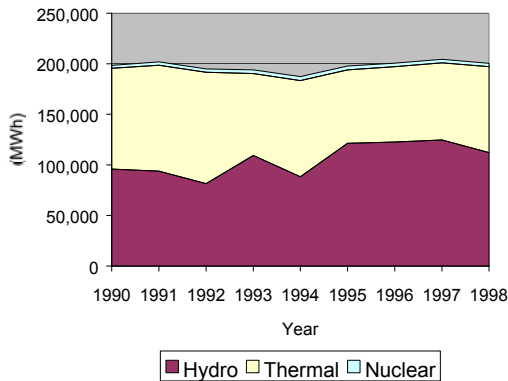


Figure 7: INEEL Annual Electricity Use by Generation Source

The INEEL annual electricity demand from thermal energy sources is shown in figure 8. The site facilities account for the vast majority of the electricity demand (97%) from thermal (coal based) utility sources (not including renewable sources such as hydropower and nuclear).

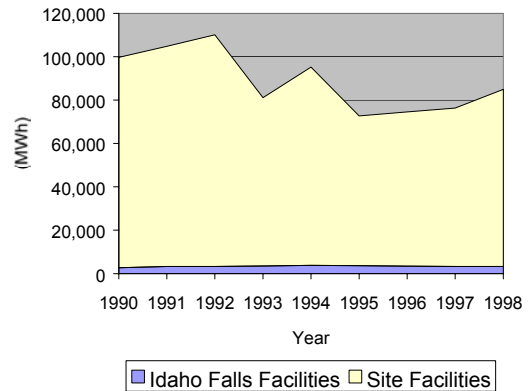


Figure 8: INEEL Annual Thermal Electricity Use by User

III. Greenhouse Gas Calculations

In this section, the general approach for calculating GHG inventories for energy and waste sectors is described. The energy sector includes emissions from facilities and transportation. The total GHG inventory includes emissions from CO₂ and photochemically important gases as described in Section I.

The methodology provided in the Revised 1996 IPCC Guidelines for National Greenhouse Inventories was used in the calculations of the INEEL greenhouse gases. These guidelines, which are well established within the global climate change community, are used in the absence of DOE implementation guidance.

The IPCC calculations include the emissions from energy use (including facility and transportation) and waste management activities. All activities are limited to anthropogenic activities and related emissions.

A standard approach is used to sum greenhouse gases emissions into an aggregate total. This unit of measure is referred to as carbon dioxide equivalents (CDE's). In this study, each of the gases is separately calculated and shown in terms of the mass of the gas (in Gigagrams) on a full molecular basis (e.g., 100 Gg CO₂). When all the greenhouse gases are combined into a total they are expressed in units of Gigagrams CDE's.

The CDE also adjusts for the relative contribution of each greenhouse gas to global warming. The CDE's estimated in this study are based on the CO₂ equivalent using a 100-year global warming potential. The Global Warming Potential (GWP) factors may be obtained through the Carbon Dioxide Information Analysis Center⁸ at ORNL.

The base year for establishment of the GHG baseline is 1990.⁹ GHG inventory data were also evaluated for the period of 1991-1998 to show trends on resource usage and GHG emissions.

⁸ Reference ORNL web site at:

http://cdiac.esd.ornl.gov/pns/current_ghg.html

⁹ All years are based on a fiscal year calendar.

Energy Calculations

The annual energy usage data for facilities and transportation (described in Section II) provide the bases for the calculation of GHG emissions. The calculations from the energy sector results in CO₂ and other non- CO₂ emissions.

The GHG emissions from energy are combined with the emissions from waste to obtain a total INEEL emission inventory. The energy emission results are provided in the tables and figures in Section V. The annual GHG emissions calculations for energy are contained in Tables 5-13 of the appendix report.

Methodology

The calculation of CO₂ emissions from fuel combustion is estimated based on the amounts of fuels used and the carbon content of the fuels. The INEEL breaks the calculation of CO₂ from fuel combustion into 6 steps:

- Step 1: Estimate Fuel Consumption.
- Step 2: Convert to a Common Energy Unit.
- Step 3: Multiply by Emission Factors to Compute the Carbon Content.
- Step 4: Compute Carbon Stored.
- Step 5: Correct for Carbon Unoxidized.
- Step 6: Convert Carbon Oxidized to CO₂ Emissions.

Non-CO₂ emissions are estimated by applying emission factors to the fuel types. The calculation of the non- CO₂ emissions (CH₄, N₂O, NO_x, CO, NMVOC) is broken into 3 steps:

- Step 1: Estimate annual fuel consumption per sector in energy units.
- Step 2: Estimate emission factors for each fuel per sector.
- Step 3: Estimate the emissions for each gas.

The calculation for SO₂ is similar to the other non-CO₂ emission calculations with the exception that SO₂ emissions are also related to the sulfur content, retention in ash, and abatement efficiency of the fuels. These additional factors are applied to the calculations of the SO₂ emissions.

Data Sources, Key Assumptions

The default values for the carbon emission factors and oxidation factors for each fuel type are based on the IPCC guidelines.

The unit conversion rates between English (e.g., BTU's) and SI (e.g., TJ) units are provided in the Table 14 of the appendix report.

The breakdown of the INEEL transportation fleet by vehicle type and fuel use is provided in Table 3 of the appendix report.

Waste Calculations

The waste calculations were developed for INEEL solid waste disposal and wastewater treatment. The calculations from the waste sector result in methane and nitrous oxide emissions.

The waste calculations were performed to obtain the GHG's from waste, which are combined with the energy GHG emissions to obtain a total GHG emission inventory. The waste emission results are shown in the figures provided in Section V. The GHG emissions from waste calculations are contained in the Excel spreadsheets provided in Tables 15-17 of the appendix report.

Solid Waste Methodology

The calculation of methane emissions from solid waste is estimated based on degradable fraction of waste that contributes to methane gas production. The INEEL methodology breaks the calculation of methane from waste into 3 steps:

- Step 1: Estimate the amount of solid waste deposited to landfills.
- Step 2: Determine the fraction of degradable organic carbon and the amount that actually degrades.
- Step 3: Compute the fraction of methane in the landfill gas.

Solid Waste Data Sources, Key Assumptions

The volume of INEEL solid landfill waste was available through existing INEEL data sources (reference: DOE/ID-10057(97), September 1998, page INEEL-7). The landfill waste from ANL-W, the EBR II, and NRF was deducted from the total waste volumes.

The solid landfill waste mass was calculated from the solid waste volumes by multiplying by a waste density factor of 747 kg/m³. This density was developed from the detailed solid waste data in pounds and cubic meters as stated in the DOE/ID-10057(97) report (pages INEEL 7-8).

Wastewater Methodology

The calculation of methane emissions from wastewater is estimated based on amount of organic material in the wastewater stream. The INEEL methodology breaks the calculation of methane from waste into 3 steps:

- Step 1: Estimate the total organic wastewater and sludge.
- Step 2: Estimate Emission factors for wastewater and sludge handling systems.
- Step 3: Estimate emission factors for sludge handling systems
- Step 4: Estimate methane emission from wastewater and sludge.

The calculation of indirect nitrous oxide emissions from human sewage are based on the following steps:

- Step 1: Estimate the total protein consumption.
- Step 2: Calculate the nitrogen content of the protein.
- Step 3: Calculate the total nitrogen using the standard emission factors (EF6) multiplied by the nitrogen content.
- Step 4: Convert nitrogen into mass of N₂O gas.

Wastewater Data Sources, Key Assumptions

Assume in the wastewater calculations that no sludge component is generated.

Assume 20.0 kg/person/year protein consumption (IPCC Guidelines).

The INEEL site population data for the years 1990-1998 were obtained from INEEL staffing. The site population used in this study was limited to the site M&O contractor and does not include ANL-W, NRF, or DOE-ID. See Table 4 of the appendix report for annual staffing numbers.

IV. Other Greenhouse Gas Generation Sectors

In addition to the energy and waste sectors, other sectors are responsible for the production of greenhouse gases. These sectors include:

- Industrial,
- Solvent and other product use,
- Agriculture,
- Land-use change & forestry.

The emissions from these sectors are not currently included in this study, but can be included in updates. These sectors may also be addressed in the INEEL Action Plans for reducing GHG by 2010. As an example, if portions of the INEEL were converted to a new land use such as biomass farming, the resulting sequestration of carbon dioxide emissions would be included (as a net carbon sink) in the GHG inventory.

Each of the four other sectors is described and areas of applicability to the INEEL are described.

Industrial

Emissions within this sector comprise by-product or fugitive emissions of GHG from industrial processes. Emissions from fuel combustion in industry are reported under the Energy sector. Examples of the types of products and industries are: mineral products (cement, lime, soda ash, asphalt roofing, road paving with asphalt), chemical industry products (ammonia, nitric acid production), metal production, pulp and paper production, production and consumption of halocarbons and SF₆ (refrigerants and air conditioning, fire extinguishers, aerosols, solvents).

INEEL Industrial Emissions

INEEL emissions from industrial fuel combustion are currently reported under the Energy sector. Potential examples of industry related GHG emissions at the INEEL include manufacture of tank armor from depleted uranium and reprocessing of spent nuclear fuel (which has been discontinued due to nuclear proliferation concerns).

Solvents

This sector covers mainly NMVOC emissions resulting from the use of solvents and other products containing volatile compounds. When the solvents are produced from petroleum products, the carbon in the NMVOC emissions will be included in the CO₂ inventory. Solvent processes and products include paint applications; degreasing & dry cleaning; and chemical products, manufacturing & processing.

INEEL Solvent Emissions

The INEEL uses solvents, paints, and chemical products across the site. The INEEL has also operated a dry cleaner facility onsite, but the site has since been shut down and decommissioned. The consumption of solvents at the INEEL may be added in future updates to this study.

Due to the active pollution prevention (P2) program at the INEEL, the emissions from these products is expected to be less than industry averages. On a global scale, the NMVOC release from solvent use is about 11 percent of the total NMVOC emissions (IPCC Reference Manual).

Agriculture

Emissions within this sector are comprised of emissions from domestic livestock, agricultural burning, and agricultural soils.

INEEL Agriculture Emissions

As a national laboratory, the INEEL generally does not perform agricultural activities that result in GHG emissions. Although changes to land use practices have begun to open sections of the INEEL to multiple uses.

One potential agricultural use of the INEEL is the free ranging of livestock on portions of the site. The ranging practice would result in emissions from enteric fermentation and manure. Biomass consumption by livestock would be assumed to be equal to the annual plant regrowth. The impacts from livestock ranging on the INEEL reservation could be evaluated as part of future updates to this study.

Other future land-use changes for the INEEL could include new agriculture uses (crops or managed grassland) which would result in additional GHG emissions in the agriculture sector.

Land Use

Land Use consists of emissions and removals of CO₂ from forest and land use change activities. These activities have impact on three different carbon sources/sinks; above ground biomass, below ground biomass, and soil carbon. Land Use includes changes to forest and other woody biomass stocks, forest and grassland conversion, abandonment of managed lands, and CO₂ emissions and removals from soil. Changes in biomass stocks may be either a source or a sink for carbon dioxide for a given year.

In a steady state condition, the withdrawal of CO₂ from the atmosphere (from photosynthesis) is balanced by the returned CO₂ from respiration of the vegetation and decay of the organic matter in soils and litter. Land use change and the use of forests directly affects the fluxes between CO₂ withdrawal and return to the atmosphere.

For example, forest clearing for agriculture by burning greatly increases the return flux of CO₂ and decreases for a while the photosynthetic flux. Subsequently, the CO₂ flux of the cleared area will reach a new steady state: the photosynthesis associated with agricultural production being balanced by the respiration of vegetation, the decay of on-site organic material, and the oxidation of the agricultural product when it is consumed, perhaps off site. However, the total amount of carbon stored in the terrestrial system will have been reduced because a forest contains more carbon than does a field of potatoes or pasture, and the removed carbon (i.e., the forest) was not put into long term storage pools. Consequently there is a net flux of CO₂ from the land (vegetation and soil) to the atmosphere.

INEEL Land Use Emissions

The INEEL lands are considered to be in a steady state condition. No significant land use changes from/or to another condition have occurred since 1990. The facility footprints at the INEEL have been established for over 10 years, and any new developments on-site are done within existing facility footprints (e.g., the Advanced Mixed Waste Treatment Facility was sited within the existing boundaries of the Radioactive Waste Management Complex).

Range fires at the INEEL result in a rapid loss of the biomass and carbon release to the atmosphere. Estimates of the impacts of range fires on GHG emissions could be evaluated for the INEEL GHG inventory. INEEL annual burned acreage is currently not included in this report.

Future scenarios for the INEEL could include developing portions of the lands within the 890 square mile reservation to enhance carbon sequestration. Possible options could include experimental production of biomass fuels, research of low-soil-erosion crop production, and brown-field conversion of D&D facilities to managed carbon sinks.

V. INEEL Greenhouse gas inventory and trend analysis

This section presents the results from the GHG calculations described in the previous sections. Table 3 provides a summary of the greenhouse gases emissions for facilities, transportation, and waste. The total INEEL greenhouse gas inventory is 186.6 Gg (CO₂ equivalent gases).

Source	GHG	Emissions (Gg on a full mole basis)	GWP	Emissions (Gg CO ₂ Equivalent)	% of Total Emissions
Idaho Falls Facilities					
	CO ₂	3.798	1	3.798	2.035%
	CH ₄	0.000	21	0.002	0.001%
	N ₂ O	0.000	310	0.015	0.008%
	NO _x	0.011		0.011	0.006%
	CO	0.001		0.001	0.001%
	NM _{VOC}	0.000		0.000	0.000%
	SO ₂	0.000		0.000	0.000%
	Sub-Total	3.810		3.827	2.050%
INEEL Site Facilities					
	CO ₂	152.324	1	152.324	81.61%
	CH ₄	0.017	21	0.347	0.186%
	N ₂ O	0.002	310	0.674	0.361%
	NO _x	0.452		0.452	0.242%
	CO	0.633		0.633	0.339%
	NM _{VOC}	0.084		0.084	0.045%
	SO ₂	0.000		0.000	0.000%
	Sub-Total	153.512		154.513	82.783%
Transportation					
	CO ₂	16.539	1	16.539	8.861%
	CH ₄	0.002	21	0.047	0.025%
	N ₂ O	0.000	310	0.043	0.023%
	NO _x	0.170		0.170	0.091%
	CO	0.714		0.714	0.383%
	NM _{VOC}	0.136		0.136	0.073%
	SO ₂	0.000		0.000	0.000%
	Sub-Total	17.562		17.649	9.456%
Waste Sector					
	CO ₂	0.000	1	0.000	0.000%
	CH ₄	0.502	21	10.542	5.648%
	N ₂ O	0.000	310	0.118	0.063%
	NO _x	0.000		0.000	0.000%
	CO	0.000		0.000	0.000%
	NM _{VOC}	0.000		0.000	0.000%
	SO ₂	0.000		0.000	0.000%
	Sub-Total	0.502		10.660	5.711%
GHG Sub-Total					
	CO ₂	172.662		172.662	92.506%
	CH ₄	0.521		10.938	5.860%
	N ₂ O	0.003		0.849	0.455%
	NO _x	0.633		0.633	0.339%
	CO	1.348		1.348	0.722%
	NM _{VOC}	0.220		0.220	0.118%
	SO ₂	0.000		0.000	0.000%
INEEL GHG Totals					
		175.386		186.649	100.000%

Table 3: 1990 INEEL Greenhouse Gas Emissions by Source/Gas

Figure 9 shows a breakdown of the contributions to greenhouse gases by facility, transportation, and waste management activities. The site facilities generate the greatest amount of gases due to facility heating, operation of laboratories and operations facilities, reactor operations, etc.

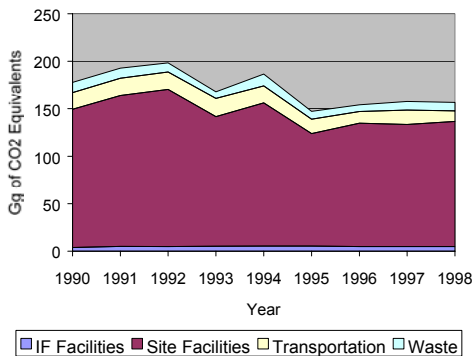


Figure 9: Annual Greenhouse Gas Emissions for All Gases by Source

Figure 10 shows that the gases contributing to the majority of GHG's are carbon dioxide (CO₂) at 92% and methane (CH₄) at 6%. The remaining 2% of the gases are (in units of carbon dioxide equivalents) are made up of the other non-CO₂ gases (CO, NO_x, N₂O, NMVOC, and SO₂).

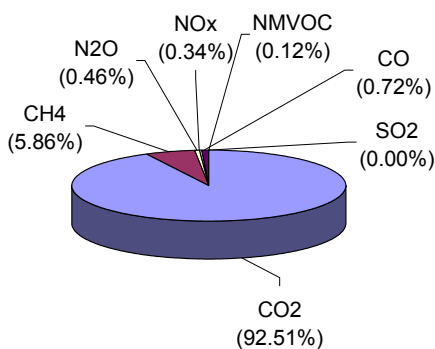


Figure 10: INEEL 1990 Greenhouse Gas Emissions (CDE) for All Sources by Gas Type

Figure 11 shows the GHG emissions for Non-CO₂ gases by source. Note that the emissions for solid waste disposal were only reported for the period of 1990-1997. For 1998, the solid waste emissions were estimated based on 1997 data.

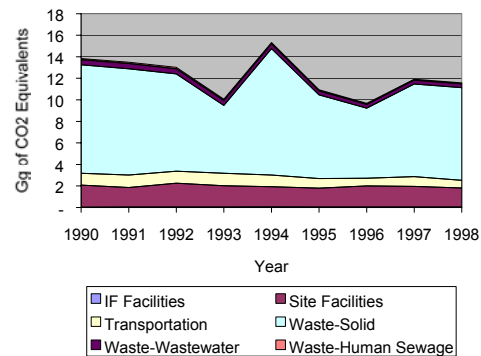


Figure 11: Annual Non-CO₂ Emission by Source

Figure 12 shows a breakdown of the other non-CO₂ gases (CH₄, CO, NO_x, N₂O, NMVOC, and SO₂). Methane (CH₄) makes up about 75% of the non-CO₂ emissions. The remaining 25% of the gases are (in units of carbon dioxide equivalents) made up of the other greenhouse and photochemically important gases.

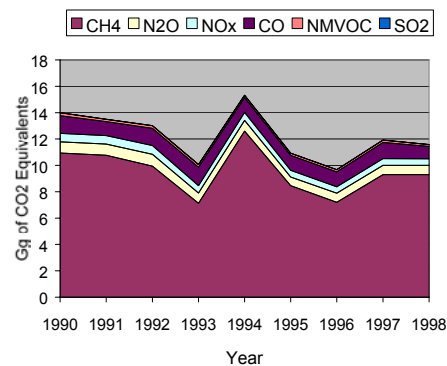


Figure 12: Annual Emissions (Excluding CO₂) for Facilities, Transportation and Waste

INEEL 2010 GHG Reduction Target

Figure 13 shows the total annual greenhouse gases for the years 1990-1998 and a line representing the targeted 2010 GHG reduction goal of 130.7 Gg (CDE). The reduction goal was established at 30% below the 1990 GHG inventory baseline of 186.6 Gg (CDE). Future actions that can be taken by the INEEL to achieve the 2010 reduction goals are provided in the Conclusions section of the report.

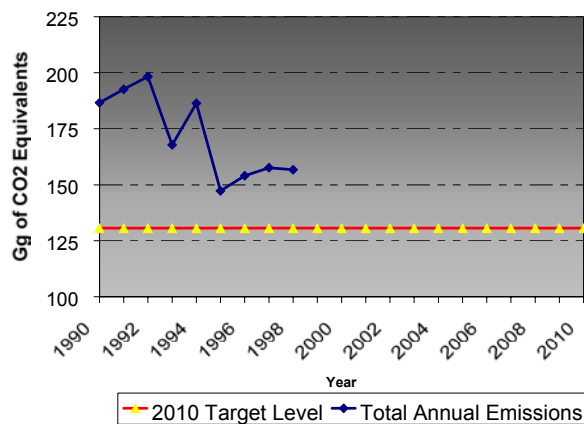


Figure 13: Targeted 2010 GHG reduction goals

Verification of Results

Currently, most greenhouse gases (CO₂, CH₄) are not regulated emissions. Actual measured INEEL site data is not available for the common greenhouse gases to verify the accuracy of these calculations. However, some non-CO₂ gases are regulated at the INEEL and data are available to check the calculations against those provided in this report.

The INEEL has prepared Air Emission Inventory reports (Idaho National Engineering and Environmental Laboratory Nonradiological Waste Management Information) annually since 1989. A summary of the data from these reports for three gases (CO, NO_x, and NMVOCs) is compiled in appendix Table 18. The methodology used to prepare the air emission

reports is based on the measurement or estimation of end of pipe emissions. The air emission methodology contrasts significantly from the IPCC methodology, which is primarily based on energy consumption and is estimated at a grosser level of detail (and at less precision). The result of this comparison was that the 1990 emissions for NO_x and NMVOC's for the INEEL facilities were within the same order of magnitude. The values of the CO from the Air Emission report were a magnitude smaller than those estimated using the IPCC method. This would suggest that the IPCC method might provide more conservative estimates (higher emission numbers) than a more detailed analysis would provide.

Uncertainty Analysis

Typical uncertainties in the emission estimates, due to the IPCC methodology, will range between:

- +/- 10% for CO₂ from fossil fuels
- +/- 20% for individual methane sources

Other specific areas of uncertainties that are specific to the INEEL include:

- Energy use of non-metered facilities and processes may lag fuel consumption by one year due to the delay in refilling bulk fuel supplies.
- Thermal electricity usage is highly contingent upon the energy available from hydropower, which is directly related to the availability of water from annual precipitation.

VI. Conclusions

The INEEL Global Climate Change (GCC) Program has sponsored the INEEL Greenhouse Gas Inventory and Trend Analysis, which, to the best of our knowledge, is the first, such analysis performed on a DOE-operated multipurpose facility. In carrying out this exercise, the laboratory has built in-house expertise, as well as many of the systems and models required to analyze carbon emissions baselines and to carry out ongoing emissions monitoring and verification.

This study provides a baseline for measurement of improvement in energy usage and greenhouse gas reductions. Although energy usage and emission reduction trends are generally positive, they are not sufficient to guarantee achievement of reduction goals. An INEEL Action Plan should be developed to provide a roadmap for taking specific actions to reduce GHG emissions to targeted goals.

Summary Results

- The total INEEL Greenhouse Gas inventory for 1990 is 186.6 Gg (CO₂ equivalent).
- Greenhouse gas generation has ranged from 106% (1992) to 79% (1995) of the 1990 baseline.
- Carbon Dioxide (CO₂) at 92% and Methane (CH₄) at 6% are the primary greenhouse gas contributors at the INEEL.
- Facilities (88%), followed by transportation (12%) are the largest fuel users that contribute to greenhouse gas generation.
- Total energy usage has held fairly constant from 1990-1997. Thermal energy use has declined by about 15% since 1990.
- INEEL greenhouse gas emission levels are significantly affected by the availability of energy from hydropower, which is affected annually by precipitation levels.
- A INEEL GHG Mitigation and Action Plan is needed to achieve the emission reduction goal of 130.7 Gg (CO₂ equivalent), to meet the 30% reduction goal from the 1990 level.

Future Actions

Future steps include:

- 1) Preparation of a detailed analysis of the INEEL GHG inventory – incorporating the DOE implementation guidance.
- 2) Developing INEEL GHG mitigation and Action Plans to meet the 2010 emission goals.
- 3) Developing unique systems capabilities to support carbon emissions offset certification and monitoring and verification.
- 4) Developing carbon-trading systems.
- 5) Advancing the science and technology in the climate change in areas such as Energy Efficiency, Clean Energy (i.e., low/non carbon fuels), Carbon Sequestration, and Climate Systems and Modeling.

Examples of actions that could result in reduced levels of INEEL GHG emissions, include:

1. Promoting energy-efficient technologies and strategies.
2. Accounting for environmental externalities in assessing the costs of energy production, resource planning, and procurement.
3. Promoting development and integration of renewable generating technologies into the electrical system.
4. Promoting high-efficiency gas generation technologies.
5. Expanding use of low-emission alternative fuels and vehicles.
6. Promoting research and development on biomass-based alcohol fuels.
7. Reducing vehicle miles traveled in personal vehicles.
8. Expanding land-use planning to improve carbon sequestration capabilities.

References

- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change, 1996.
- US Environmental Protection Agency, *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*, EPA 230-B-92-002, November 1992.
- US Environmental Protection Agency, *States Guidance Document: Policy Planning To Reduce Greenhouse Gas Emissions*, Second Edition, May 1998.
- DOE-ID, 1998, *Idaho National Engineering and Environmental Laboratory Nonradiological Waste Management Information for 1997 and Record to Date*, DOE/ID-10057(97), September 1998.
- DOE-ID, 1998, *Air Emission Inventory for the Idaho National Engineering and Environmental Laboratory – 1997 Emissions Report*, DOE/ID-10646, June 1998.
- DOE-ID, 1997, *Air Emission Inventory for the Idaho National Engineering and Environmental Laboratory – 1996 Emissions Report*, DOE/ID-10594, June 1997.
- DOE-ID, 1996, *Air Emission Inventory for the Idaho National Engineering and Environmental Laboratory – 1995 Emissions Report*, DOE/ID-10537, June 1996.
- DOE-ID, 1995, *Air Emission Inventory for the Idaho National Engineering Laboratory – 1994 Emissions Report*, DOE/ID-10516, July 1995.
- DOE-ID, 1994, *Air Emission Inventory for the Idaho National Engineering Laboratory – 1993 Emissions Report*, DOE/ID-10437(93), June 1994.
- DOE-ID, 1993, *Air Emission Inventory for the Idaho National Engineering Laboratory – 1992 Emissions Report*, DOE/ID-10437(92), June 1993.
- DOE-ID, 1992, *Air Emission Inventory for the Idaho National Engineering Laboratory – 1990 & 1991 Emissions Report*, DOE/ID- AEI Update, June 1992.
- Glavin, C., T. Foust, K. Walton, *Idaho National Engineering and Environmental Laboratory: Global Climate Change Federal Opportunity Assessment*, INEEL/INT-99-TFCG001, Revision 1, September 1999.