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Inventory of Carbon Dioxide (CO_2) Emissions at Pacific Northwest National Laboratory

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Pacific Northwest
NATIONAL LABORATORY

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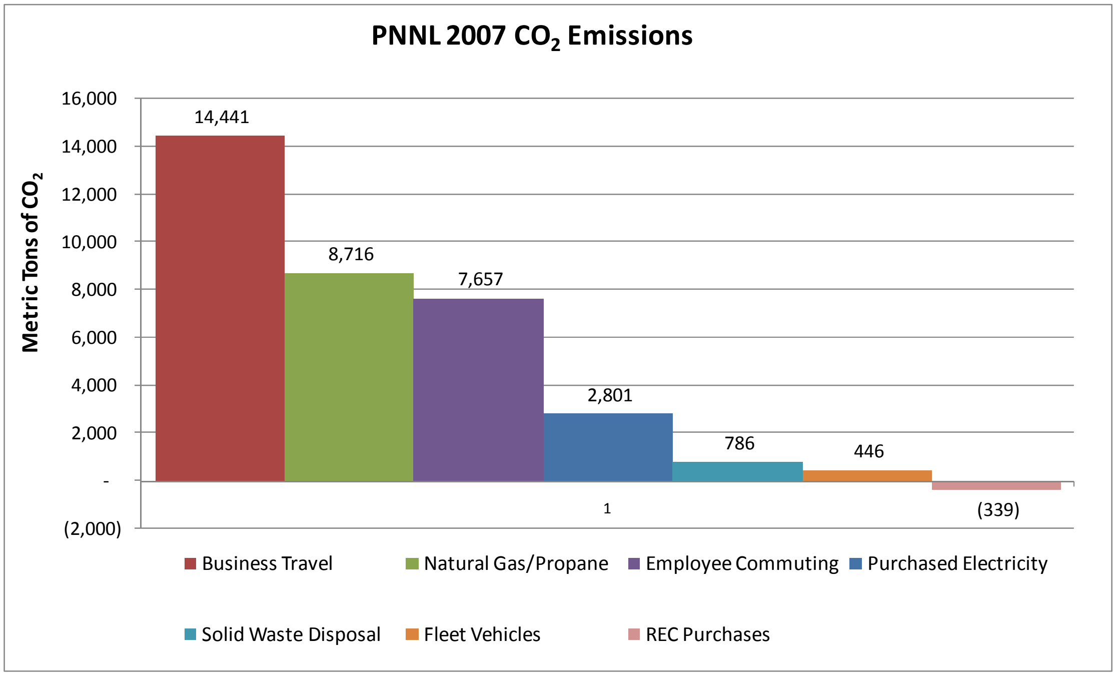
Executive Summary

The Pacific Northwest National Laboratory (PNNL) conducted its first complete carbon dioxide (CO_2) emissions inventory for the 2007 calendar year. A CO_2 emissions inventory, or carbon footprint, examines how an organization's activities contribute to climate change in terms of the greenhouse gas (GHG) emissions it produces. The goal of this preliminary inventory is to provide PNNL staff and management with a sense for the relative impact different activities at PNNL have on the Lab's total carbon footprint.

PNNL's CO_2 emissions in calendar year 2007 were estimated at 36,378 metric tons of CO_2 equivalent. The most significant contributors to PNNL's carbon footprint, as illustrated in the graph below, come from business travel (about 41% of total emissions) and on-site fuel consumption (natural gas and propane) (25%), followed by employee commuting (22%) and consumption of purchased electricity (8%). PNNL's net carbon emissions in 2007 totaled 34,848 metric tons of CO_2, which reflects a reduction in emissions from the Lab's purchase of "green power" or Renewable Energy Certificates (RECs). REC purchases represented 12% of PNNL's total electricity consumption in 2007.



Establishing a baseline carbon inventory represents an important first step in effectively managing GHG emissions associated with PNNL's operations. The next step will be to act on this information by setting targets to reduce PNNL's emissions (e.g. reduce CO_2 emissions by 25% of 2007 levels by 2012). Once targets are set, emissions avoidance and reduction opportunities should be assessed in terms of the impact on PNNL's carbon footprint, operations, and cost, and implemented as possible with available budgets. To have a meaningful impact on PNNL's carbon footprint, emission reduction activities should address the major contribution areas identified above. Examples of activities that may help reduce PNNL's carbon footprint include:

- Increase the energy efficiency of all PNNL data centers and major server clusters. Improvements may include consolidation of disparate research servers into a centralized data center, use of server virtualization technology, broader use of economizers for free cooling, evaluating the impact of increasing room cooling temperature a few degrees, and improved airflow management such as localized cooling in server racks.
- Deploy onsite power sources using renewable (e.g. photovoltaics) and more efficient hydrocarbon-based technologies, through power purchase agreements when it is more cost effective.
- Implement employee training in the efficient use of fume hoods and invest in technology improvements (e.g. variable air volume fume hoods) when new equipment is needed.
- Tune boilers to achieve optimal fuel-oxygen ratio and optimize operations for the size and type of boiler.
- Encourage employees to turn off equipment and lights when not in use, and ensure that information technology policies enable and encourage equipment shutdown whenever possible.
- Encourage use of teleconferencing, video conferencing, and web conferencing by offering periodic training and easier accessibility to equipment.
- While not a direct reduction measure, purchasing carbon credits for air travel and charging to project budgets would help to offset the impact of travel. For the average trip, the carbon credits would cost approximately $8.
- Support expansion and use of local carpooling/ridesharing and vanpool programs by working with Ben Franklin Transit and facilitating links to online ride-matching resources.
- Offer financial incentives to employees who utilize alternative methods of commuting.
- Establish regular carbon footprint messages to all staff with information on specific actions individuals can take to reduce the Lab's carbon footprint, including examples of how specific staff members took steps to reduce the Lab's footprint.

Finally, PNNL is committed to reporting its CO_2 emissions annually and tracking progress against goals. Based on this initial inventory, efforts will be made to streamline data management systems to better support the acquisition of data necessary to support future inventory development.

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1.0 Introduction and Background

In recent years, Pacific Northwest National Laboratory (PNNL) has been harnessing its world class science and technology to help shape the nation's approach to global climate and energy security challenges. We are investing in a targeted set of science, technology, and policy analysis activities that will not only advance society's understanding of climate change, but help optimize strategies for mitigating and adapting to climate impacts.

As leaders in the field of carbon management, PNNL believes that conducting a carbon inventory and committing to aggressively manage our carbon footprint represents an important opportunity to *walk the talk*, by integrating the latest science, technology and policy thinking into the Lab's own operations. Furthermore, it directly supports our research in areas such as energy efficiency technologies and green building by improving our understanding of what carbon management means at the organizational level. Finally, we believe it provides PNNL with first-hand experience in carbon markets, which will better prepare us to respond to future state and federal cap-and-trade legislation on emissions reporting and carbon credit trading.

While a formal inventory was not conducted until 2007, it merits noting that PNNL has been working to manage many aspects of its carbon footprint with some very positive results. For example, in 2006 the lab switched from use of fossil fuels to bio-based fuels in its large-scale boilers and backup generators. Energy use in campus buildings in 2007 had been reduced 43 percent from the FY85 baseline. Energy use in industrial and laboratory facilities had been reduced 46 percent from the FY90 baseline. But there are still opportunities to do more. This study highlights areas where efficiency improvements and changes in the way PNNL operates could have the greatest impact on the Lab's footprint.

2.0 Methodology

2.1 Introduction

The approach used to estimate PNNL's inventory and begin identifying emissions reduction opportunities is based on guidance provided in the World Resources Institute's (WRI) *Hot Climate, Cool Commerce: A Service Sector Guide to GHG Management.* PNNL has initiated the process of designing the inventory and has calculated our carbon emission contribution areas, as illustrated in Figure 1. Proposed next steps are to establish reduction targets, implement emissions reduction projects, purchase carbon offsets for some portion of remaining emissions, and report our inventory through a public registry.

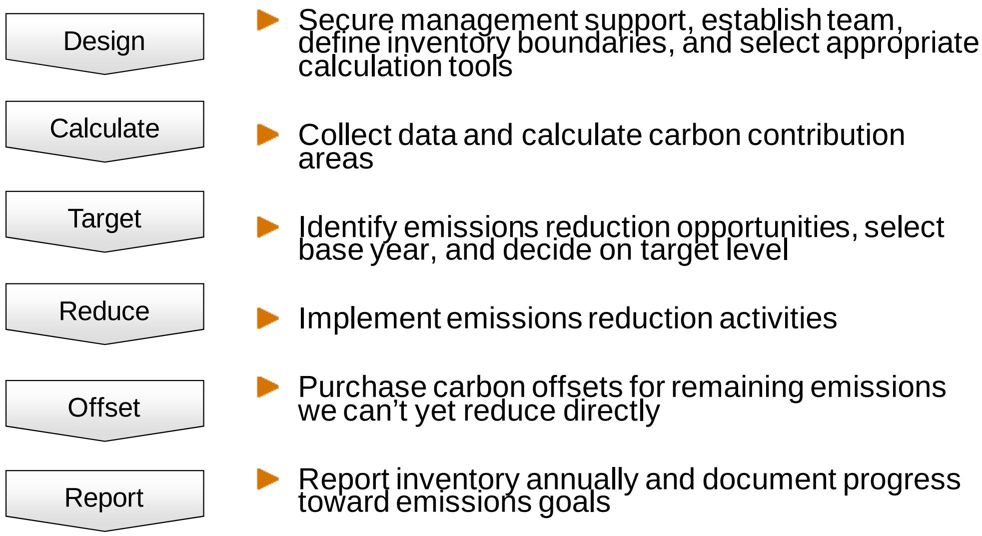

Figure 1. Approach to assessing and managing our carbon footprint.

The *Greenhouse Gas Protocol Corporate Accounting and Reporting Standard* (GHG Protocol) developed by WRI and the World Business Council for Sustainable Development was used as a basis for most CO_2 emissions calculations (see www.ghgprotocol.org). The GHG Protocol has become the international standard for corporate GHG inventory development and serves as the accounting and reporting foundation for several voluntary and mandatory GHG programs, such as The Climate Registry and the U.S. Environmental Protection Agency's (EPA) Climate Leaders. This protocol includes Excel-based calculation tools, which were customized to support specific emissions sources at PNNL. Alternative tools were incorporated to support the emissions calculations for which the GHG Protocol does not currently provide guidance.

2.2 Quality Assurance

The inventory was completed by a team of staff members from PNNL using data from our Environmental Management System (EMS) and other databases. To ensure accuracy of the inventory a reviewer from PNNL checked calculations, conversion, and emissions factors in inventory spreadsheets.

2.3 Boundaries

Establishing boundaries and scope of analysis is an important first step in designing an organization's carbon inventory. Many aspects of an organization's carbon footprint are difficult to quantify, so data availability will drive what is accounted for. Emissions categories included in an inventory will also vary across organizations because those that are important in one organization may not significantly contribute to another's overall inventory. For PNNL's carbon emissions inventory, boundaries were established using guidance from the GHG Protocol, and modified to accommodate PNNL operations.

2.3.1 Operational Boundaries

PNNL's carbon emissions inventory includes facilities over which it has ownership and/or direct operational control, and data available. This includes facilities on the Richland, Washington and Sequim, Washington campuses. Operation of smaller, leased facilities such as those in Seattle and Portland, as well as home offices of offsite staff, were not considered for some aspects of this analysis (e.g. electricity consumption) due to challenges associated with data collection from these sites, lack of control over many emissions areas, and the fact that emissions from these locations are relatively small compared to those from the Richland and Sequim campuses.

2.3.2 Scope Boundaries

The GHG Protocol defines three categories of carbon emissions, as described below.

- **Scope 1 – Direct emissions**: Emissions from sources that the organization directly controls, including on-site fuel production and fuel use in company-owned vehicles.
- **Scope 2 – Electricity indirect emissions:** Emissions normally generated off-site by the local utility company, and thus are emissions that the reporting organization does not directly control. However, they are usually significant contributors to an organization's overall carbon footprint and can be reduced by organizational efficiency measures.
- **Scope 3 – Other indirect emissions:** Other emissions from activities required to get the organization's products or services to market but not controlled by the organization. These can include employee commuting, business travel (from commercial airplanes, rental cars, employee-owned vehicles, and/or trains), production of raw materials for goods purchased, processing and transportation of purchased materials (e.g. paper products, computers), waste management activities, and outsourced services. Scope 3 emissions are often the most challenging to quantify.

Most public registries and emerging regulatory schemes require reporting of Scope 1 and 2 emissions, with Scope 3 emissions being optional. PNNL included emissions from Scope 1 and 2, and some Scope 3 activities, as characterized in Figure 2 below.

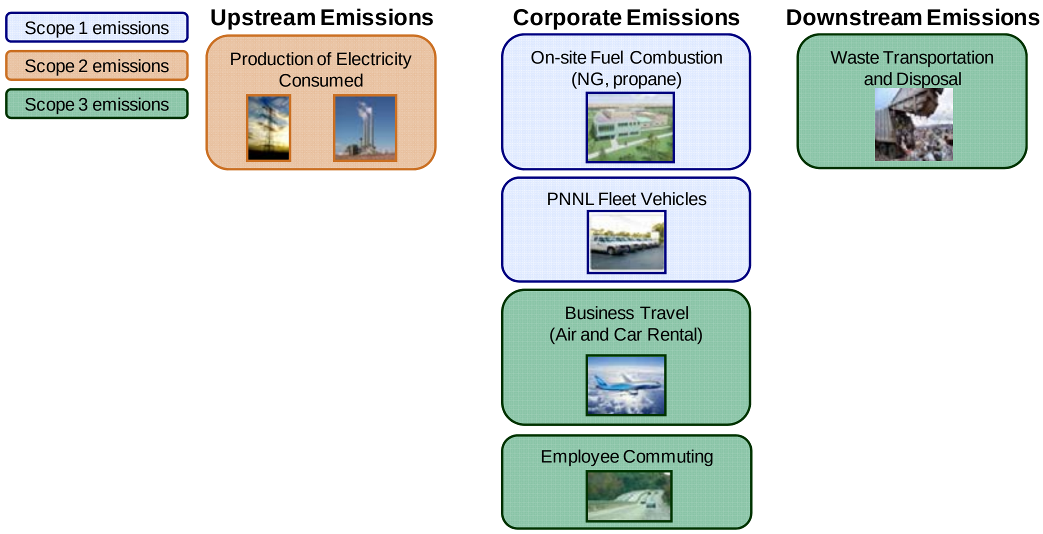

Figure 2. Scope of PNNL's carbon inventory.

2.4 Reporting Period

Calendar year 2007 was chosen as the base year for the first inventory, although for some emissions categories data was only available for the fiscal year 2007. An effort was made to collect data from 2003 to provide an earlier baseline for trend monitoring, however consistent data was not available for comparison.

2.5 Data Collection and Calculation Methodology

To calculate the emissions associated with all of PNNL's activities, a formula of activity data multiplied by an emission factor gave a total CO_2 equivalent number, usually expressed in metric tons of CO_2, as illustrated:

(Activity Data) X (Emission Factor) = GHG Emissions

The emission factors used in this report were published through local, state, or national agencies, and were usually provided in the GHG Protocol calculation tools. A summary list of emission factors used in this analysis is provided in Appendix A.

2.5.1 Scope 1 – Direct Emissions from Fuel Use in Facilities

2.5.1.1 On-site Fuel Combustion

On-site fuel combustion at PNNL includes natural gas and propane. Natural gas is used to power boilers that heat some facilities (i.e., RTL, RRC, EMSL, and the 300 area). Natural gas usage has decreased significantly since 1990 due to energy efficiency retrofits and some conversions to all-electricity heating. In 2007, PNNL consumed 1,467,593 therms of natural gas.

The emissions calculation for natural gas fuel consumption is illustrated in Figure 3 below. Emissions from CO_2, CH_4, and N_2O were converted into a total CO_2 equivalent.

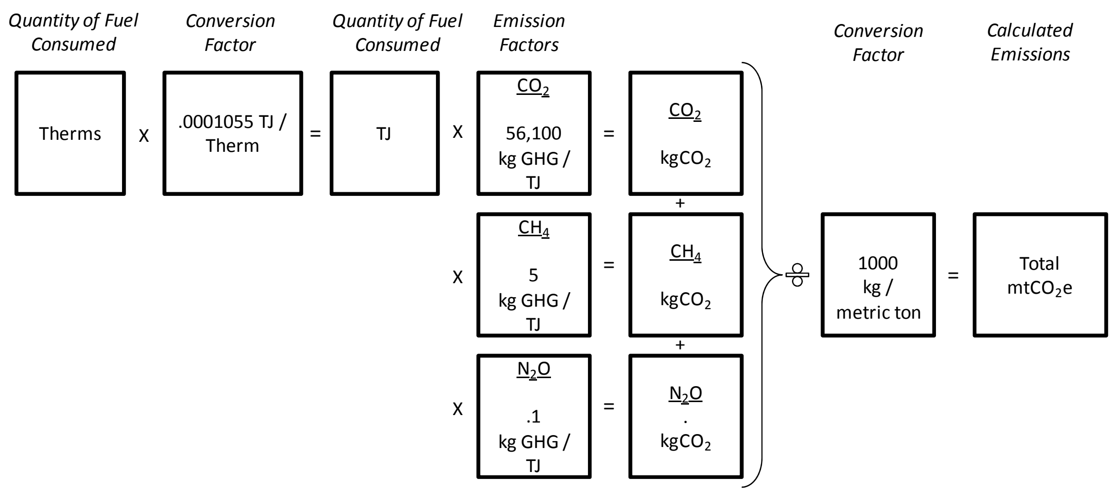

Figure 3. Method for calculating natural gas emissions.

Propane is used for heating in one building on the PNNL campus. In 2007, PNNL consumed 1,598 gallons of propane. The emissions calculation for propane used at PNNL is shown in Figure 4.

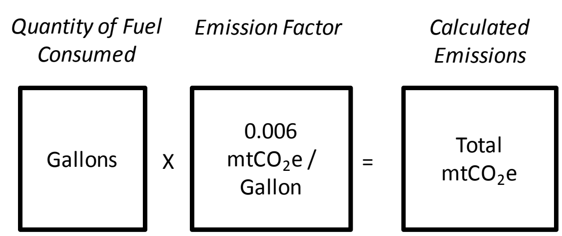

Figure 4. Method for calculating propane emissions.

The GHG Protocol provided emission factors for natural gas. Emission factors for propane use were derived from the DOE Voluntary Reporting of Greenhouse Gases Program.[1]

2.5.1.2 Fleet Vehicles

PNNL has a fleet of approximately 168 government and privately owned vehicles, which are used for grounds maintenance, security, mobile laboratories, and other purposes. The majority of the vehicles are pickup trucks or sport utility vehicles, with a small number of “micro vehicles” that are about two-thirds the size of a standard pickup truck. PNNL fleet vehicles use three different types of fuel: gasoline, diesel, and ethanol mix (E85). Currently, 38 vehicles operate exclusively on E85, and efforts are in place to increase the number of flex fuel vehicles. Figure 5 shows the emissions calculation for fleet vehicle fuel consumption for each of the three fuel types consumed.

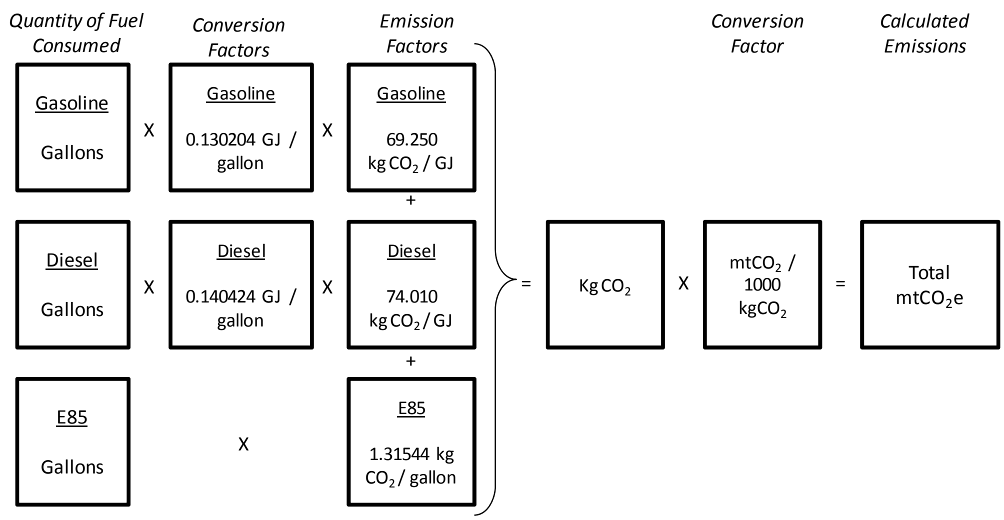

Figure 5. Method for calculating fleet vehicle emissions.

The GHG Protocol provided conversion and emission factors for gasoline and diesel use. E85 emission factors came from the DOE Voluntary Reporting of Greenhouse Gases Program.[2]

2.5.2 Scope 2 – Indirect Emissions from Electricity Purchased

Scope 2 emissions at PNNL consist of purchased electricity and Renewable Energy Certificates (RECs), which represent a reduction in PNNL's net carbon footprint.

2.5.2.1 Purchased Electricity

PNNL consumed 90,365,048 kWh of electricity to support campus operations in Richland and Sequim, Washington during 2007.[3] Much of the electricity load at PNNL is driven by the demands of the high performance computing and laboratory equipment that enables PNNL to conduct world-class research. For example, the Environmental Molecular Sciences Laboratory (EMSL), which at the time contained a supercomputer, mass spectrometers, and other equipment with extremely high power draws, required 23,547,600 kWh (26% of total electricity use) to support its operations alone.

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[1] U.S. Department of Energy, Voluntary Reporting of Greenhouse Gases Program. Simplified Emissions Inventory Tool (SEIT). Available at: http://www.eia.doe.gov/oiaf/1605/Forms.html.

[2] U.S. Department of Energy, Voluntary Reporting of Greenhouse Gases Program. Simplified Emissions Inventory Tool (SEIT). Available at: http://www.eia.doe.gov/oiaf/1605/Forms.html.

[3] PNNL reports energy use data to DOE based on the fiscal year. Data for the calendar year was not available. All data reported for electricity and RECs is based on the fiscal year.

Emission factors selected to calculate emissions associated with an organization's electricity consumption can vary significantly. Emerging guidance for public sector GHG accounting and reporting recommends using emissions factors associated with the local supplier's specific fuel mix to provide the most accurate calculation of electricity emissions. PNNL purchases electricity exclusively from the City of Richland, Washington, which is predominantly powered by hydropower and nuclear. The fuel mix for Sequim, Washington (provided by Clallum County PUD) is very similar. Because a specific emissions factor were not available from the utilities, and a tool was not available through the GHG Protocol to produce an emissions factor from a specific fuel mix, PNNL used the Clean Air-Cool Planet Campus Carbon Calculator to calculate Scope 2 emissions levels for the two local utility fuel mixes. The resulting calculation was used as a basis for PNNL's Scope 2 emissions.[4]

The methodology underlying the Clean Air Cool Planet calculator for Scope 2 electricity emissions is illustrated in Figure 6 below.

Electricity Purchased	Transmission and Distribution Losses	Purchased Electricity Energy Content	Custom Fuel Mix	Source Energy Output	Source Generation Efficiency	Source Energy Input
Total kWh	9%	Total kWh X MMBtu/kWh	%	% of total fuel mix X Purchased electricity content = MMBtu	%	Energy Output / Generation efficiency = MMBtu

Cont.

2007 Fuel Mix (City of Richland)

Bio-mass	0.09%
Coal	2.57%
Cogeneration	0.00%
Geothermal	0.00%
Hydro	85.66%
Landfill Gases	0.00%
Natural Gas	1.06%
Nuclear	10.49%
Other	0.00%
Petroleum	0.03%
Total	100.00%

Coal	33%
Natural Gas	40%
Distillate Oil (#1-#4)	32%
Residual Oil (#5-#6)	32%
Nuclear	33%
Waste to Energy	22%
Hydro-Electric	34%
Wood Biomass	23%
Renewable (Wind, Solar)	34%

[4] Clean Air-Cool Planet Campus Carbon Calculator is available for free download at: http://www.cleanair-coolplanet.org/. See custom fuel mix worksheet.

Source CO_2 Emissions Factor	Scope 2 CO_2 Emissions	Source CH_4 Emissions Factor	Scope 2 CH_4 Emissions	Source N_2O Emissions Factor	Scope 2 N_2O Emissions	Total Scope 2 Emissions
kg CO_2 / MMBtu	kg CO_2	kg / MMBtu	Source Energy Input X Source CH4 emissions factor = kg	kg / MMBTU	Source Energy Input X Source N20 emissions factor = kg eCO_2	kg CO2 + (kg eCO2 for CH4 X GWP)+ (kg eCO2 for N2O X GWP)= MT eCO_2

Coal	93.45
Natural Gas	52.76
Distillate Oil (#1-#4)	72.37
Residual Oil (#5-#6)	77.96
Nuclear	0.00
Waste to Energy	23.84
Hydro-Electric	0.00
Wood Biomass	0.00
Renewable (Wind, Solar)	0.00

Coal	0.00106
Natural Gas	0.00106
Distillate Oil (#1-#4)	0.00317
Residual Oil (#5-#6)	0.00317
Nuclear	0.00000
Waste to Energy	0.00000
Hydro-Electric	0.00000
Wood Biomass	0.03165
Renewable (Wind, Solar)	0.00000

Coal	0.00158
Natural Gas	0.00011
Distillate Oil (#1-#4)	0.00148
Residual Oil (#5-#6)	0.00148
Nuclear	0.00000
Waste to Energy	0.11828
Hydro-Electric	0.00000
Wood Biomass	0.00422
Renewable (Wind, Solar)	0.00000

Figure 6. Method for calculating purchased electricity emissions.

When supplier-specific emissions factors are not available, it is recommended that regional grid emission factors be used. These emissions factors are associated with the North American Electric Reliability Council (NERC) regions and EPA's corresponding eGrid subregions.[5] PNNL's reference area, the Western Electricity Coordinating Council / Northwest Power Pool (WECC/NWPP) subregion, covers an eight-state area in the West, including several states with coal-intensive electricity mixes.[6] As a result the subregion emissions factor is much higher than that associated with the local utility for the City of Richland. While PNNL did not use the subregion factor as a basis for its inventory given guidance to use local when available, emissions using the regional factor were calculated for reference. It is possible the reporting requirements under future regulatory schemes will require use of regional factors, so PNNL wanted to understand how that would impact its Scope 2 emissions.

[5] U.S. Environmental Protection Agency. eGRID2007 Version 1.0, Year 2005 Summary Tables. Available at: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2007V1_0_year05_SummaryTables.pdf.
[6] U.S. Environmental Protection Agency. eGRID2007 Version 1.0, Year 2005 Summary Tables. Available at: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2007V1_0_year05_SummaryTables.pdf.

2.5.2.2 Renewable Energy Certificates (RECs)

A REC is a tradable commodity that represents proof that one megawatt-hour (MWh) of power is produced through an eligible renewable energy resource (e.g. wind, solar, geothermal). Because they represent electricity purchased from a renewable, non-carbon emitting source, REC purchases reduce PNNL's net carbon emissions.

During 2007, PNNL purchased 10,947,289 kWh of renewable energy from non-hydropower sources, representing 12% of PNNL's total electricity consumption.

An emissions factor for REC purchases was derived based on the calculation of electricity emissions for the local utility fuel mix by dividing total CO2 emissions (converted to pounds) by the total kWh consumed. These emission savings from the use of non-hydro renewable power are subtracted from PNNL's total carbon footprint.

The emissions reduction calculation for RECs is shown in Figure 7 below.

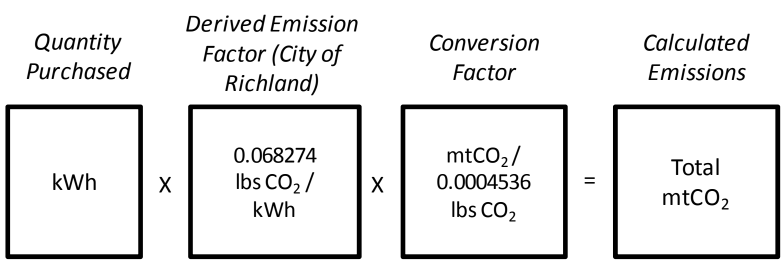


Figure 7. Method for calculating REC emissions reduction.

2.5.3 Scope 3 – Other Indirect Emissions

Scope 3 emissions that were accounted for at PNNL included business travel, employee commuting, and waste disposal and transportation. Because the GHG Protocol does not yet provide calculation guidance or tools for waste management and paper consumption, other GHG emission tools were employed to help gauge the relative contribution of these two emissions categories to PNNL's overall footprint. Calculations of emissions from paper consumption were excluded from the final analysis because the calculation methodologies used were unclear.

2.5.3.1 Business Travel

To understand the impact of business travel on PNNL's carbon footprint, emissions were calculated for both air travel and car travel in rental cars. Data was not available to assess the impact of business car travel using personal cars at the time of this analysis.

Air Travel

As a contract research and consulting organization for agencies and private companies around the world, business travel is essential to support PNNL's work. During 2007, PNNL flew an estimated 23,543 domestic roundtrips and 3,203 international roundtrips. Data on air travel was acquired through PNNL's travel agency, TMP.

The GHG Protocol tool provides a distance-based method to calculate the emissions associated with business travel. Trips are defined as short, medium, or long haul. Each classification has a different associated emission factor, as more fuel is consumed during takeoff and landings than during straight flight. A short haul is a one-way trip less than 500 km, a medium haul is any trip between 500 and 1600 km, and a long haul is any trip over 1600 km. The GHG Protocol uses emission factors published by the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA).

TMP was able to provide data on the number of trips between two cities but not total distances traveled or flight segments. For routes that were traveled most often, distances were calculated by mapping the route, then classifying the trip as short, medium, or long. Using this method, over 70% of domestic trips and almost 40% of international trips were accounted for by examining the most frequently traveled routes. The calculated ratio of short, medium, and long trips from the sample data was then applied to the remaining trips for which distance was not calculated. An average distance per trip for short, medium, and long haul trips was calculated based on the sample data and multiplied by the total number of trips in each category to arrive at a total distance of short, medium, and long haul trips.

The emission calculation for business air travel is shown in Figure 8.

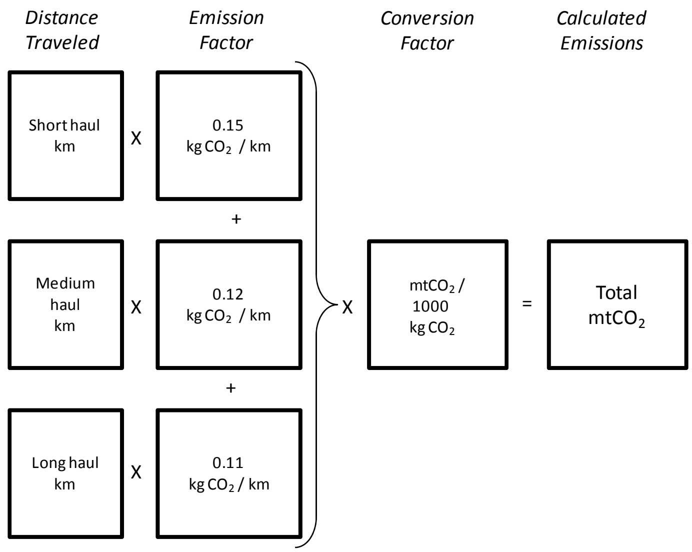


Figure 8. Method for calculating emissions from air business travel.

Rental Car Travel

Emissions associated with rental car usage can be calculated based on distance traveled or fuel consumed, the latter of which provides more accurate emissions calculations. Data to support fuel consumption calculations was available through PNNL's travel expense reporting system.

The travel expense reporting database was queried for total fuel receipts filed by travelers. An average price per gallon of gasoline of $2.767 in 2007 was used to calculate the total estimated gallons of gasoline used in rental cars.[7] Emission factors for motor gasoline came from the U.S. Energy Information Administration (EIA).[8]

The emission calculation for business travel in rental cars is shown in Figure 9.

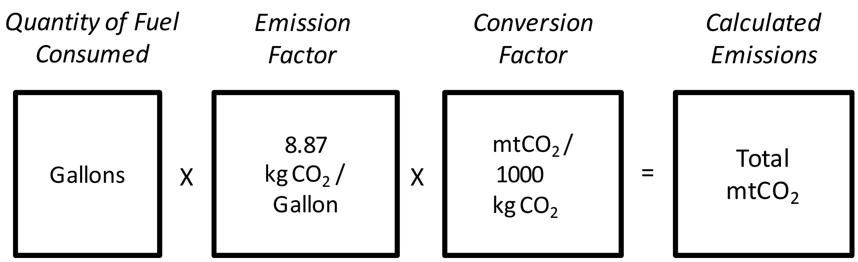


Figure 9. Method for calculating emissions from business travel in rental cars.

2.5.3.2 Employee Commuting

PNNL's 4127 employees are geographically distributed across the Richland campus, Sequim, Seattle, Portland, the Washington, DC metropolitan area, and other locations, all of which provide different options for commuting. To calculate emissions from employee commuting, an on-line survey was developed, modeled after the GHG Protocol employee commute survey tool, and distributed to all employees. The survey response rate was 49%.

For survey respondents who commuted by automobile, an approach based on fuel consumption by fuel type (i.e. gasoline, diesel, E85) was used to calculate total emissions from driving. The survey first derived an estimated number of "commuting weeks" in the calendar year for each respondent by estimating an average number of hours worked per year after vacation and holidays (PNNL's average for planning purposes is 1832 hours), and subtracting the average number of days worked from home, the average number of days spent on business travel, and any time on extended leave during the calendar year. U.S. average vehicle fuel economy data for

[7] Gas price data came from the U.S. Energy Information Administration. Available at: http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html. Assumes regular conventional gas formulation.

[8] Emission coefficients came from the U.S. Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program. Available at: http://www.eia.doe.gov/oiaf/1605/factors.html.

different vehicle types (e.g. passenger, SUV, hybrid)[9] was then used to calculate total fuel consumption, and a fuel-specific emission factor[10] was used to arrive at total CO_2 emissions.

The emissions calculation for employee commute by automobile is shown in Figure 10:

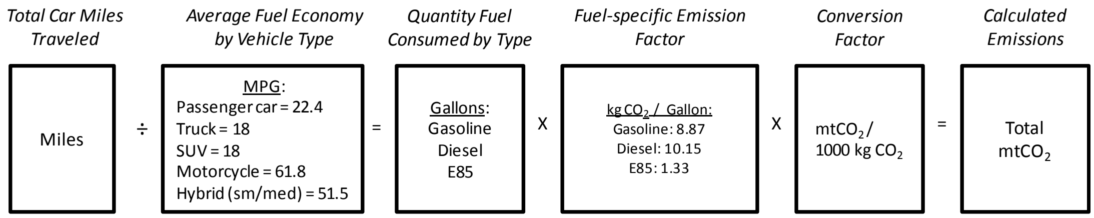


Figure 10. Method for calculating employee commute emissions.

For those who used alternative modes of transportation (e.g. subway, bus) distances traveled were multiplied by established emissions factors for the specific mode of transportation used to arrive at total emissions.

2.5.3.3 Waste Management

PNNL wanted to account for emissions associated with waste management and recycling to make this analysis as comprehensive as possible. The PNNL Pollution Prevention team currently calculates estimates of waste that is landfilled, recycled, and composted. However, these are very crude estimates based on quarterly visual assessments of how “full” waste bins are at the time of pickup and what proportion of the total content different materials represent (e.g. office paper, cardboard, glass, plastics). In 2007, it was estimated that PNNL produced 496 metric tons of landfilled waste and 369 metric tons of recycled waste. These numbers include waste from the PNNL Richland campus only, as data is not currently available for waste produced at Sequim or other sites.

Currently the GHG Protocol does not provide a method or tool to support such analysis. The most widely used and accepted tool currently available to calculate emissions associated with waste management and recycling is the EPA Waste Reduction Model (WARM). WARM calculates GHG emissions for baseline and alternative waste management practices, including source reduction, recycling, combustion, composting, and landfilling, and reports them in metric tons of CO_2 equivalent. Users provide data on a wide range of material types commonly found in municipal solid waste, such as plastics, office paper, and cardboard, for which emissions factors have been established. The factors were developed using a life-

[9] U.S. Department of Transportation Bureau of Transportation Statistics. National Transportation Statistics 2008,Table 4-23: Average Fuel Efficiency of U.S. Passenger Cars and Light Trucks. Available at: http://www.bts.gov/publications/national_transportation_statistics/html/table_04_23.html. Fuel economy of hybrid vehicles came from “2008 Guidelines to Defra’s GHG Conversion Factors: Methodology Paper for Transport Emission Factors.” Available at http://www.defra.gov.uk/environment/business/reporting/pdf/passenger-transport.pdf

[10] All emissions factors for employee commute methods came from the GHG Protocol.

cycle assessment methodology that accounts for upstream emissions from material production and downstream from the point of use. Recycling counts as avoided emissions that benefit an organization's overall carbon footprint.[11]

While this life-cycle calculation is useful to help PNNL estimate emissions from waste management and set goals for improvement, there are problems associated with double counting upstream and downstream emissions, which will be accounted for in others' inventories. The tool developers do not recommended use of the WARM tool for formal GHG inventory reporting because of this. As result, PNNL included emissions associated with waste disposal and transportation only, and did not include avoided emissions from recycling and composting.

3.0 Analysis and Results

3.1 Emissions Calculations

PNNL's total net CO_2 emissions for 2007 are presented in

Table 1. Net CO_2 emissions represent the sum of emissions from Scope 1, 2 and 3 sources less the emissions savings associated with purchases of "green power" or RECS.

Table 1. PNNL 2007 CO2 emissions.

Category of Emissions	2007 CO_2 Emissions (metric tons)	% of Total Emissions	Description
Scope 1: Direct	8,716	24%	Natural Gas/Propane Consumption
	446	1%	Fleet Vehicles
Subtotal	**9,163**		
Scope 2: Indirect from Purchased Electricity	2,801	8%	Consumption of Purchased Electricity
	(339)		*REC Purchases*
Subtotal	**2,462**		
Scope 3: Other Indirect Emissions	14,441	40%	Business Travel
	7,657	25%	Employee Commuting
	786	2%	Solid Waste Disposal
Subtotal			
Total CO_2 Emissions	**22,884**		
Net CO_2 Emissions	**34,848**		

[11] U.S. Environmental Protection Agency. User's Guide for WARM. Available at: http://epa.gov/climatechange/wycd/waste/calculators/Warm_UsersGuide.html.

As is illustrated in Figure 11 and Figure 12 below, the largest contributors to PNNL's carbon footprint are business travel (41% of total emissions) and natural gas and propane consumption (25%), followed by employee commuting (22%) and consumption of purchased electricity (8%).

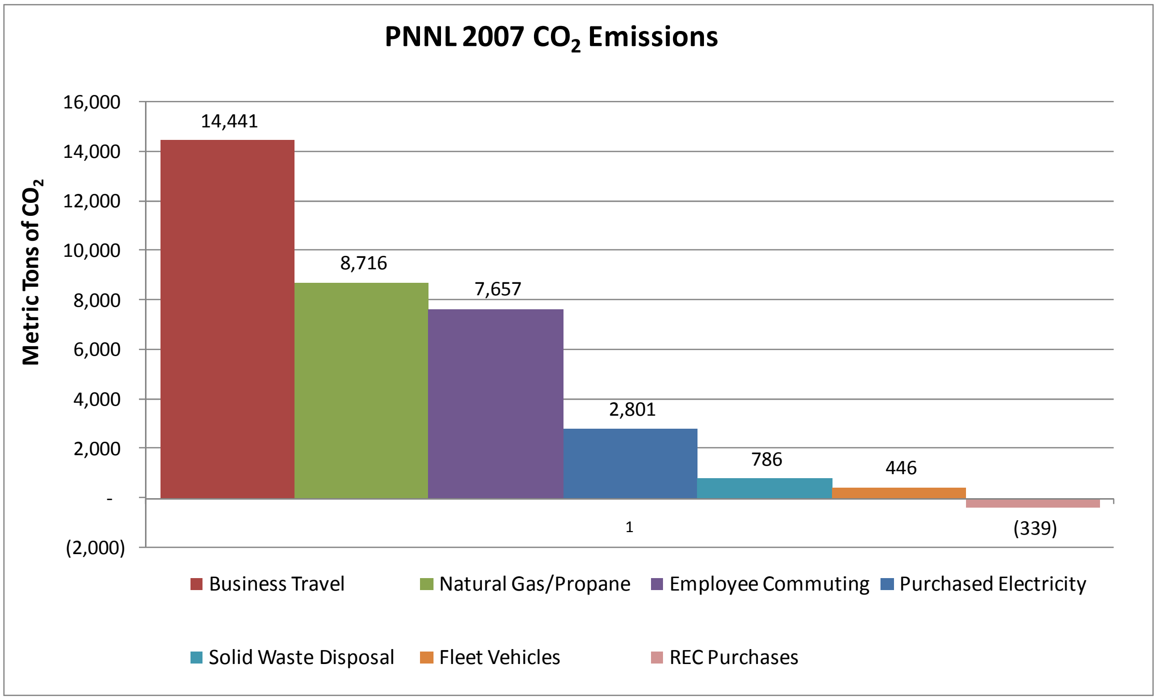


Figure 11. PNNL 2007 total CO_2 emissions by emissions category.

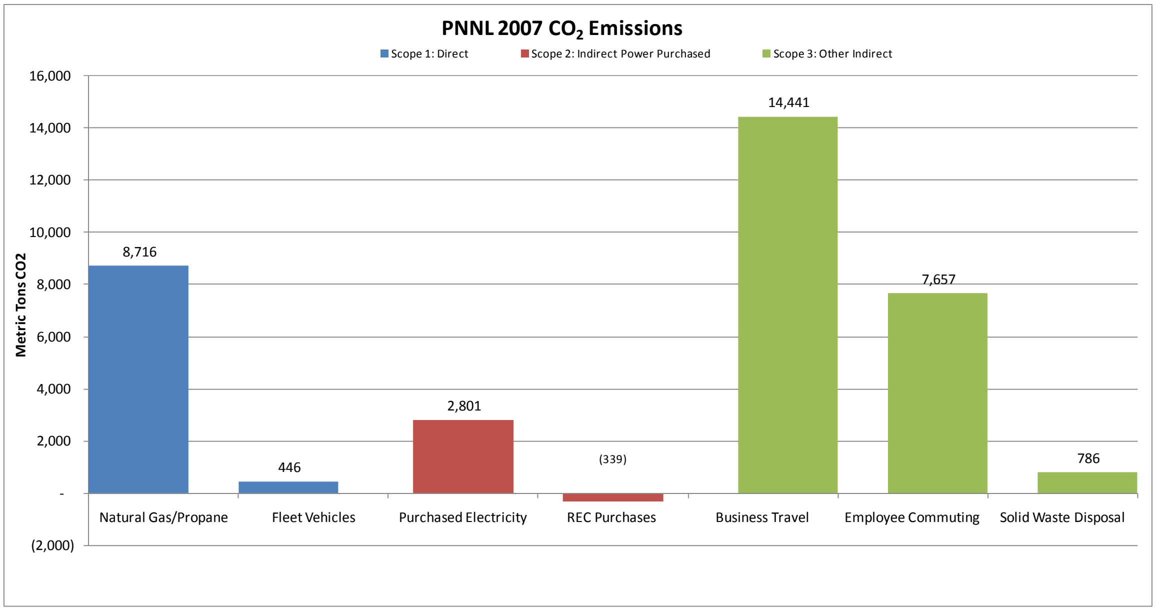


Figure 12. PNNL 2007 total CO_2 emissions by GHG scope category.

3.2 Lessons Learned about the Inventory Process

Developing a CO_2 inventory is a significant undertaking. While a number of useful guidelines and supporting calculation tools exist (e.g. WRI's GHG Protocol), a fair amount of customization is required to develop a robust inventory and protocol that can be used for future inventories. Several important lessons were learned through this initial process that will facilitate future CO_2 inventory analyses at PNNL.

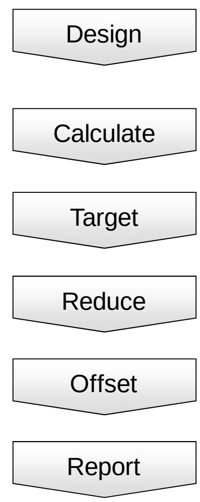
- **Improve data collection and data management process –** Data to support this analysis came from various data coordinators across PNNL. Some of this data is incorporated into PNNL's environmental management system and other data was pulled from human resources, accounting, travel, and other individual performance metric owners. To facilitate data collection for future inventories, it is recommended that inventory developers work with the EMS team members and the other data holders to track information in a way that supports a calendar year analysis and in a format that better supports reporting requirements. For example, if the travel agency were able to track and report total actual air miles traveled by flight segment, rather than reporting city pairs traveled, which does not account for stopovers and requires an extra step to determine mileage between cities, that would provide a more accurate picture of PNNL's business travel impact and would greatly facilitate calculations. It is recommended that this information be tracked and reviewed by the EMS team members on a quarterly basis and integrated into PNNL's EMS. Once a common system is in place to collect, manage, and verify the quality of the data, future inventories will require significantly less effort.

- **Seek additional calculation tools** – The initial scope of this inventory was defined more broadly than is often done for corporate GHG inventories, by attempting to include emissions associated with waste/recycling and paper products consumed. While third-party tools are currently available to support an assessment of emissions associated with both of these activities, there are uncertainties involved with the calculation methodology for paper and the waste/recycling calculation has issues associated with double counting upstream emissions. The GHG Protocol development team reports that they will be providing additional guidance and tools to support analysis of other Scope 3 emissions in the future. PNNL should track progress and incorporate such methodologies and tools into its inventory analysis as possible in order to provide a more comprehensive picture of PNNL's operations impact and to support target-setting for emission reductions in these areas.

- **Conduct analysis by building and/or organizational unit** – In order to use the inventory results to effectively identify opportunities for improvement over time, the inventory should be conducted at a finer level of granularity, for example at the building level and group level rather than institution level. The current analysis presents aggregate data for the Richland and Sequim facilities over a calendar year period.

- **Expand organizational boundaries** – In order to better represent the true scale of PNNL's operations, data associated with PNNL's other off-site campuses in Seattle, Portland, and Washington, DC should be included for all emissions categories in future analyses. In the current analysis, electricity use is not included for all offsite buildings, due to data collection challenges in the time frame available, yet other emissions categories (e.g. business travel and employee commuting) account for offsite staff.

4.0 Future Steps



As outlined in the introduction to this analysis, designing a carbon footprint inventory with the appropriate boundaries and calculation methods, collecting data, and calculating PNNL's major GHG emission contribution areas are essential first steps in effectively managing GHG emissions associated with PNNL's operations.

The next important step will be to act on this information by setting targets to reduce PNNL's emissions (e.g. reduce CO_2 emissions by 25% of 2007 levels by 2012). Once targets are set, emissions avoidance and reduction opportunities should be assessed in terms of the impact on PNNL's carbon footprint, operations, and cost, and implemented as possible with available budgets. Examples of some of these activities are discussed in the following section.

An ambitious goal to strive for would be to become a carbon neutral organization. While dramatic reductions in emissions could be achieved through efficiency gains, demand-side management/changes in behavior, and reductions in GHG intensity of energy sources, in the near-term getting to net-zero emissions purely through emissions reduction projects will not be feasible. Emissions that cannot be readily reduced can be offset through the purchase of carbon credits. Carbon credits are sold through voluntary markets and are generated from investments in emissions reducing projects, such as renewable energy or energy efficiency projects. An investment in carbon offsets could enable PNNL to achieve, or get closer to, carbon neutrality. More information on carbon offsets can be found in Appendix B.

A final step in the path to managing PNNL's carbon footprint is to publicly report PNNL's CO_2 inventory and progress toward emissions reduction goals on an annual basis. Public reporting instruments such as EPA's Climate Leaders and The Climate Registry can provide an added level of rigor, verification, and credibility to an emissions inventory, while also helping to raise visibility about the organization's CO_2accounting and management efforts.

4.1 Emissions Reduction Strategies

PNNL has considerable experience developing and implementing technologies and approaches to demand-side management, energy efficiency, and lower-impact energy production. To achieve emissions reduction targets and have a meaningful impact on our carbon footprint, PNNL's emission reduction activities must address the "big four" contributors to our footprint: business travel, employee commuting, on-site fuel combustion, and purchased electricity. A list of example emissions reduction strategies under consideration in of the major emissions categories is presented below.

Opportunities to reduce emissions from business travel include:

- Setting management and group travel goals and having TGMs work with staff to reduce the number of trips per employee
- Encouraging use of teleconferencing, video conferencing, and web conferencing by offering periodic training and easier accessibility to equipment
- While not a direct reduction measure, purchasing carbon offsets for air travel and charging them to projects can help offset the overall impact of PNNL's business travel
- Encouraging use of public transit while on travel when possible, as an alternative to renting a car. Work with TMP to let employees know what transit options exist in cities on their itinerary.
- Making compact/economy or hybrid cars, as available, the default rental car choice rather than mid-sized cars

Opportunities to reduce emissions from on-site fuel combustion include:

- Optimizing operations for the size and type of boiler
- Tuning boilers to achieve optimal fuel-oxygen ratio
- Ensuring outside air dampers are working correctly
- Installing CO_2 sensors for ventilation rate control
- Reducing infiltration by sealing doors, window, etc.

Opportunities to reduce emissions from employee commuting focus on encouraging employees to choose alternatives to single-occupancy car transport. Examples include:

- Launching an education campaign on alternatives to single occupancy vehicle commuting and their benefits.
- Supporting expansion and use of local carpooling/ridesharing and vanpool programs
- Providing campus-wide ride support with electric vehicles to minimize personal vehicle needs at work
- Offering financial incentives to employees who utilize alternative methods of commuting. This might include reimbursing employees for fixed amount of expenses associated with the purchase or repair of a bicycle used for commuting.[12]

[12] Section 211 of the HR1424, The Emergency Economic Stabilization Act of 2008, would provide employers with a tax break of $20 per month per cycling employee.

Opportunities to reduce emissions from the purchase of electricity include:

- Increasing the energy efficiency of all PNNL data centers and major server clusters. Improvements may include consolidation of disparate research servers into a centralized data center, use of server virtualization technology (which increases server utilization rates by enabling them to run multiple applications), expanded use of economizers for free cooling, evaluating the impact of increasing room cooling temperature a few degrees, improved airflow management and using localized cooling in server racks.
- Deploying onsite power sources using renewable (e.g. photovoltaics) and more efficient hydrocarbon-based technologies, using , power purchase agreements when it is more cost effective
- Implementing training and technology improvements to reduce energy used to operate fume hoods (e.g. variable air volume fume hoods)
- Encouraging employees to turn off equipment and lights when not in use, and ensure that information technology policies enable and encourage equipment shutdown whenever possible
- Building retrofits, such as a green roof or coating the roof with reflective paint, can reduce energy required to heat and cool the building
- Updating old or poorly working equipment in leased facilities (e.g. chillers, economizers) with more efficient equipment

Appendix A: Emission Factors

Activity	Units	Conversion Factors	Emission Factors	Source
Combustion of natural gas	therms	.0001055 TJ / therm	56.100 mtCO2 /TJ .005 mt CH4 / TJ .0001 mt N2O / TJ	GHG Protocol / 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy
Combustion of propane	gallons		.000572 mtCO2 / gallon	U.S. Department of Energy, Voluntary Reporting of Greenhouse Gases Program, Simplified Emissions Inventory Tool (SEIT)
Gasoline use in fleet vehicles	gallons	0.130204 GJ energy / gallon	.06925 mtCO2 / GJ	GHG Protocol / 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy
Diesel use in fleet vehicles	gallons	0.140424 GJ energy / gallon	.007401 mtCO2 / GJ	GHG Protocol / 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy
E85 use in fleet vehicles	gallons		.00131544 mtCO2 / gallon	U.S. Department of Energy, Voluntary Reporting of Greenhouse Gases Program, Simplified Emissions Inventory Tool (SEIT)
Electricity consumption	kWh	.36 lbs / kWh (WA State factor)	.0001633 mtCO2 / kWh	U.S. Environmental Protection Agency, eGRID2007 Version 1.0, Year 2005 Summary Tables
Business air travel	km		Short flight: 0.00015 mtCO2 / km Medium flight: 0.00012 mtCO2 / km Long flight: 0.00011 mtCO2/ km	United Kingdom Department for Environment, Food and Rural Affairs (DEFRA)
Business car travel	miles		Small gas car: 0.00026 mtCO2 / mile Med gas car: 0.00030 mtCO2 / mile Large gas car: 0.00035 mtCO2 / mile	United Kingdom Department for Environment, Food and Rural Affairs (DEFRA)
Gasoline for employee commuting	gallons		.00887 mtCO2 / gallon	U.S. Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program
Diesel for employee commuting	gallons		.01015 mtCO2 / gallon	U.S. Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program
E85 for employee commuting	gallons		.01015 mtCO2 / gallon	U.S. Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program

Appendix B: Overview of Carbon Offsets

Carbon offsets or credits are investments in projects outside of an organization's boundaries that sequester or reduce CO_2 equivalent levels in the atmosphere. These might include fossil fuel reduction, bio-carbon sequestration, bio-gas capture, and technological sequestration projects. The purchase of carbon offsets through voluntary carbon markets provides an important mechanism for organizations to help address climate change – *not as a substitute for emissions reduction activities, but as a complement to avoid a net increase in emissions from an organization's operations.*

Offsets vary dramatically in quality and price. To implement a credible offsetting program, it is important to buy high quality assets from reputable offset providers. High quality offsets are real, tangible projects with accepted methodologies resulting in measureable, permanent reductions that are verified through a third party, enforceable by legal instruments, and synchronized to ensure that offset time period matches the emission time period. Renewable energy and industrial carbon reduction schemes generally deliver the highest quality credits, whereas biological sequestration (e.g. tree planting projects) can be of questionable carbon quality due to possible challenges in measuring reductions and ensuring the permanence of the offsets.

Offsets can be purchased on the voluntary carbon market either through the "Over The Counter" (OTC) market or the Chicago Climate Exchange, which is a voluntary but legally binding, membership-based cap-and-trade emission scheme. Credits are purchased by the metric ton of CO_2 equivalent and can vary in price from $1 to over $100 per metric ton. The wide range of costs for offsets reflects the variability of type and credibility. Due to the increasing demand for carbon offsets, it is expected that prices will continue to rise over the upcoming years. The table below outlines some of the most common types of voluntary offsets and associated costs.

Carbon offset mechanisms[13]

Offset Type	**Representative Cost** (per metric ton CO_2 equivalent)	**Cost Range** (per metric ton CO_2 equivalent)	**Notes**
Verified Emissions Reductions (VERs)	$10	$1-45	Represent bulk of voluntary market. Lack of specific rules for project definition leads to wide quality range. Emerging standards (e.g. Gold Standard) helps buyers screen for quality.
Certified Emission Reductions (CERs)	$25	$20-35	Certified through CDM (Kyoto protocol). Rigorous requirements and higher cost.
Chicago Climate Exchange credits (CFIs)	$5	$1-$10	Traded only by CCX members. Criticized for lack of transparency. Several companies have withdrawn.
Renewable Energy Credits (RECs)	$15	$5-$30	Economical but controversial as offsets. Not always tested for additionality and ownership of the offset difficult to define.

[13] Ewing, Tejas. April 2008. The ENDS Guide to Carbon Offsets 2008. Published by Environmental Data Services, London.