THE MERRIAM-POWELL GREENHOUSE GAS PROJECT

Greenhouse Gas Emissions at Northern Arizona University: Strategies for Reduced Emissions

Interdisciplinary Approaches to Climate Change Mitigation
Spring, 2007

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Students from different disciplines came together during the Spring 2007 semester to document past and current emissions of greenhouse gases at Northern Arizona University, and to provide suggestions for reducing these emissions. This document summarizes our findings.

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1 Introduction

This report of greenhouse gas emissions at Northern Arizona University and strategies for reducing them results from an interdisciplinary climate change mitigation study undertaken by undergraduate and graduate students at Northern Arizona University (NAU) during the Spring, 2007 semester. Our class had two goals: to define NAU's contribution to global warming, and to assess the university's best options for reducing its greenhouse gas emissions (GHG) at NAU's Flagstaff mountain campus. Our work is intended to help NAU meet the American College and University Presidents Climate Commitment, signed by President Haeger earlier this year. By signing on, President Haeger joined a small group of college and university presidents leading the way by committing to reducing their own institutions' greenhouse gas emissions. Following is a description of the methods used to calculate GHG emissions at NAU and the mitigation options developed for four emission sectors: electricity, transportation, natural gas, and waste and land management.

In February, 2007, the Intergovernmental Panel on Climate Change confirmed that humans are very likely to have caused the warming observed over the past hundred years, and that continued emissions of greenhouse gases by human activity will warm the planet further. Human societies emit greenhouse gases by driving cars, heating buildings, growing food, harvesting forests, and raising livestock: all these activities produce carbon dioxide, methane, and nitrous oxide, the three major greenhouse gases warming the Earth.

2 Methodology

2.1 Clean Air Cool Planet calculator

We used the Clean Air-Cool Planet's Campus Carbon Calculator v 5.0 (Beta)[1] to inventory current and past greenhouse gas emissions at Northern Arizona University. Historical data for Northern Arizona University's emissions was collected from numerous sources and entered into the Calculator. Developed specifically for universities, the calculator quantifies GHG emissions that result from university operations, including: purchased electricity, natural gas, transportation, and waste and

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[1] http://www.cleanair-coolplanet.org/

land management. Emissions are calculated based on historical activity in each sector and converted into a standard metric of metric tons carbon dioxide equivalen ($MTCO_2e$, see 2.2.1 below). We limited our analysis to the Mountain Campus of Northern Arizona University, which includes 36 academic buildings, 39 administrative/dining services buildings, residence halls and a married housing complex. We included landfill emissions caused by on-campus waste, all on-campus activities, and statistics for commuting and air-travel for University related business in our NAU GHG assessment. We did not include GHG emissions caused by on-campus construction or production of materials or equipment

2.2 Metrics

To analyze potential emission reductions from each sector, total emissions of greenhouse gases (as $MTCO_2e$) and the net present value for reduced or avoided emissions ($NPV/MTCO_2e$) were chosen as key metrics used to compare estimated project emissions from different sectors. This section gives a short description of each.

2.2.1 Metric Tons of CO_2 Equivalent

There are many gases contributing to global warming. The emissions targeted in this study include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), the three most important greenhouse gases contributing to human-caused global warming. Because these gases differ in the amount of warming they cause[2] (see Table 1), we converted all emissions to a common metric, called carbon dioxide equivalents (CO_2e)[3]. For a given amount of CH_4 emissions, for example, the comparable CO_2e is the amount of carbon dioxide that would be needed to cause the same amount of warming. This is analogous to converting foreign currencies to a common basis before trading. By using CO_2e as a standard metric, each emissions source and potential reduction strategy can be quantitatively compared, whether that source or strategy involves direct emissions of CO_2, N_2O, or CH_4.

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[2] Global warming potentials are based on the heat-absorbing ability of each gas relative to that of CO_2, as well as the amount of the gas removed from the atmosphere over a given number of years relative to that of CO_2 (http://www.eia.doe.gov/oiaf/1605/gwp.html).

[3] Global warming potentials and atmospheric lifetimes taken from US EPA Non-CO_2 Gases Economic Analysis and Inventory (http://www.epa.gov/nonco2/econ-inv/table.html)

Table 1 Global Warming Potentials and Atmospheric Lifetime (Years)

Gas	Atmospheric Lifetime	Global Warming Potential
Carbon Dioxide (CO_2)	50-200	1
Methane (CH_4)	12±3	21
Nitrous Oxide (N_2O)	120	310

2.2.2 NPV/MTCO$_2$e

Another way in which mitigation strategies between sectors can be compared is by calculating the net present value (NPV) for each option per $MTCO_2e$ reduced. The NPV is the value today of all the future costs (e.g. maintenance) and benefits (e.g. reduction in electricity bills), including the initial cost of the project. The NPV is then divided by the GHG emissions reduction over the project period. This value is given in \$/$MTCO_2e$, which represents the cost (negative values) or savings (positive values) per metric ton of CO_2e reduced by the proposed project.

2.3 Emissions Targets

These emissions targets represent goals set by different entities, which will be used as benchmarks for possible future emissions reductions at NAU. Meeting these emissions goals will best be accomplished through increases in efficiency, as well as exploring participation in a carbon offsetting program. These offset programs allow net reductions of greenhouse gas emissions through proxies who reduce their emissions or increase their absorption of greenhouse gasses.

2.3.1 Arizona

In 2006, Governor Janet Napolitano signed Executive Order 2006-13, establishing carbon emission reduction goals for the state of Arizona.[4] In this executive order, the goals recommended by the Climate Change Action Group include:

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[4] Executive Order 2006-13, http://azgovernor.gov/dms/upload/EO_2006_13_090806.pdf

- Reducing greenhouse gas emissions in Arizona to year 2000 levels by the year 2020,
- A further reduction to 50% below year 2000 levels by 2040, and
- To explore strategies to reach year 2000 levels by the Arizona Centennial in 2012.

These emissions targets represent the least ambitious of the three targets considered, but are also the most feasible.

2.3.2 Kyoto

The Kyoto Protocol was an agreement made under the United Nations Framework Convention on Climate Change[5] that set mandatory targets on greenhouse gas emissions for all signatory nations. This agreement is the cornerstone of the international community's attempt to combat global warming. Although the United States has not ratified the protocol, the reduction target for the U.S. still represents the standards set by the majority of the rest of the world's nations, and is a very feasible and visible goal for NAU to strive towards. The Kyoto Protocol calls for a reduction of greenhouse gas emissions to 7% below 1990 levels by 2012.[6]

2.3.3 Carbon Neutrality

Carbon neutrality represents the pinnacle of possible greenhouse gas reduction targets. Carbon neutrality is the state where all sources of greenhouse gas emissions are either eliminated entirely, or are equally offset by other means. Achieving "carbon neutrality as soon as possible" is the stated goal of The College and University Presidents' Climate Commitment, to which NAU's President Haeger is a founding signatory.

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[5] http://unfccc.int/

[6] "Countries included in Annex B to the Kyoto Protocol and their emissions targets", http://unfccc.int/kyoto_protocol/background/items/3145.php

3. Northern Arizona University's GHG Footprint

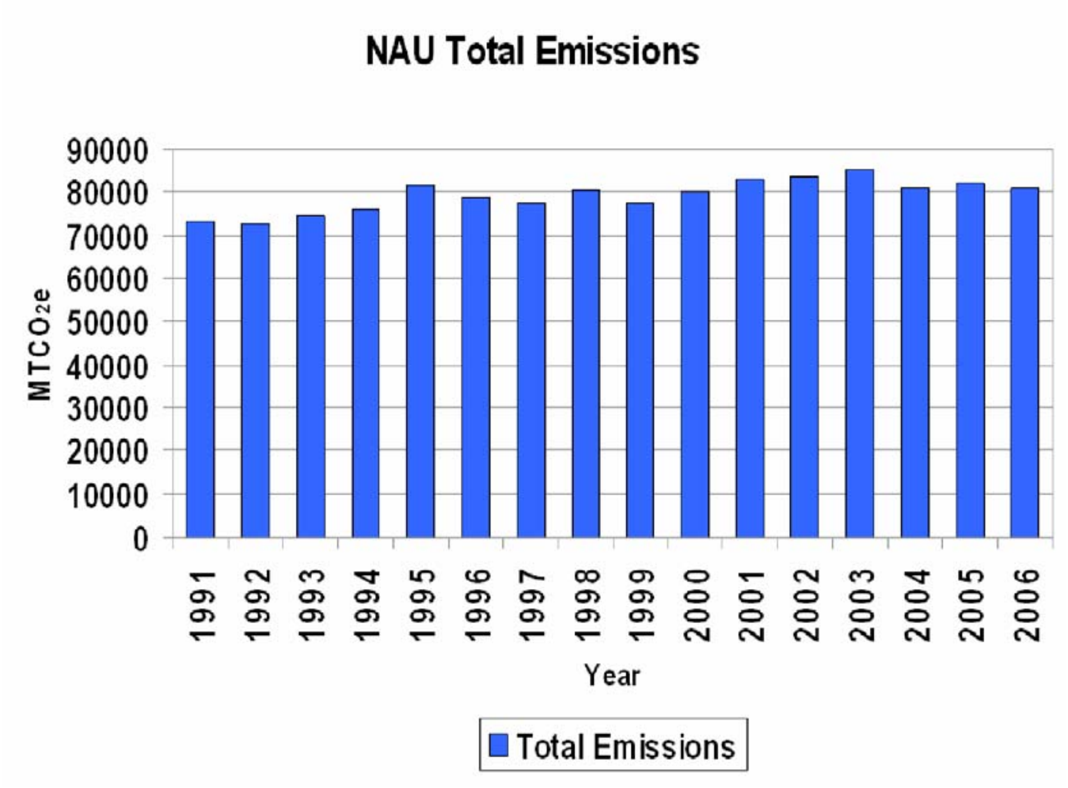

Figure 1: **Total emissions from 1991 to 2006**

3.1 Historical

Using data gathered from numerous sources around campus and the Clean Air Cool Planet calculator (2.1) we estimated NAU's emissions from the past 16 years. This data are shown in Figure 1. There is a slight increase in total greenhouse gas emissions over this period, a time when growth of the student population was negligible. Emissions of greenhouse gases per student increased from 5.12 to 6.83 $MTCO_2e$, so growth in the student population does not explain the increase observed. Total square footage of NAU building space increased sharply over this time period, which undoubtedly contributes to the increased emissions. Projections for future emissions are covered in the next section.

3.2 Projections

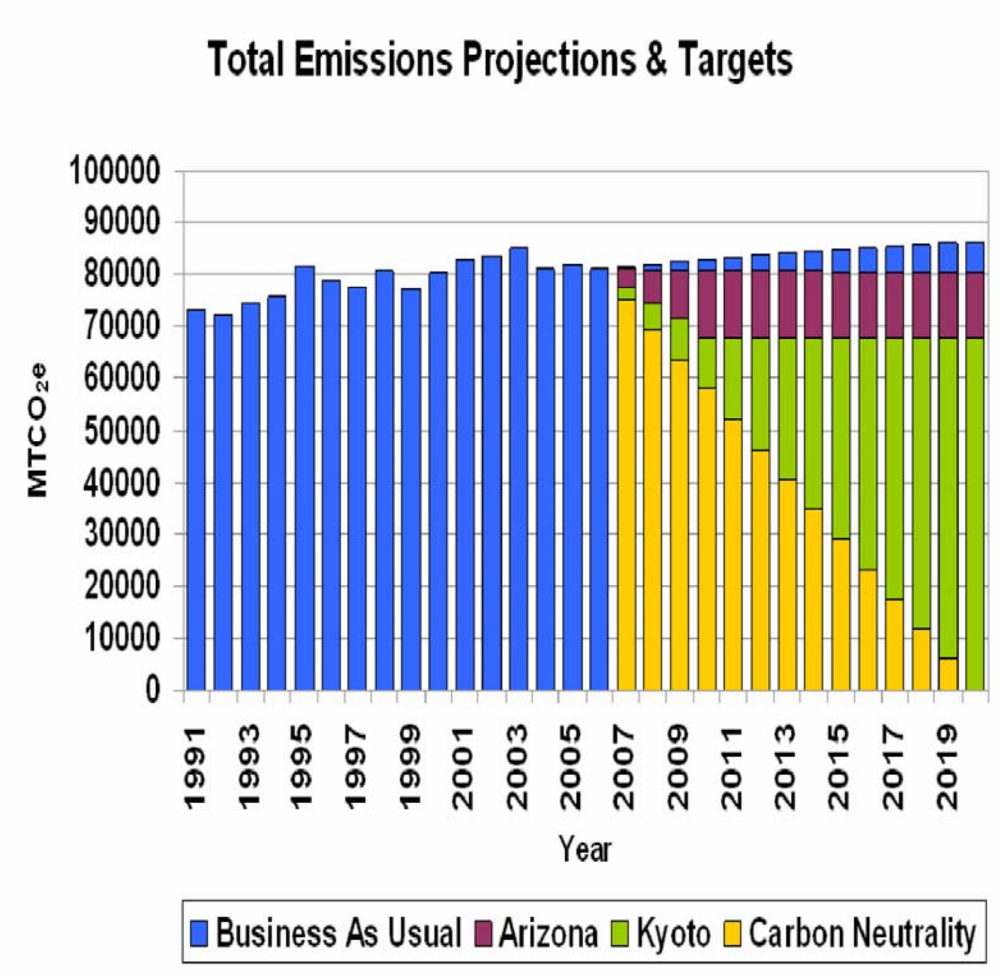

Figure 2: **NAU Emissions Projections (With Targets)**

Past emissions and possible future scenarios are shown in Figure 2. Projections for each of the targets discussed in Section 2.3 along with a business as usual scenario are presented from 2007 to 2020. The first projection (in blue) shows expected emissions for *business-as-usual*. This projection assumes a growth rate of emissions equal to the past average, with a 5% reduction each year (for example, as newer, more efficient buildings replace older ones). Targets for the state of Arizona, for the Kyoto Protocol, and for Carbon Neutrality are also illustrated. NAU's relatively slow rate of growth in emissions in the past means that it will be easier to meet targets that are tied to past emissions (e.g., AZ, Kyoto), compared to other entities where emissions have grown far more rapidly (e.g., the state of Arizona, the US).

4 Sector Project Evaluations

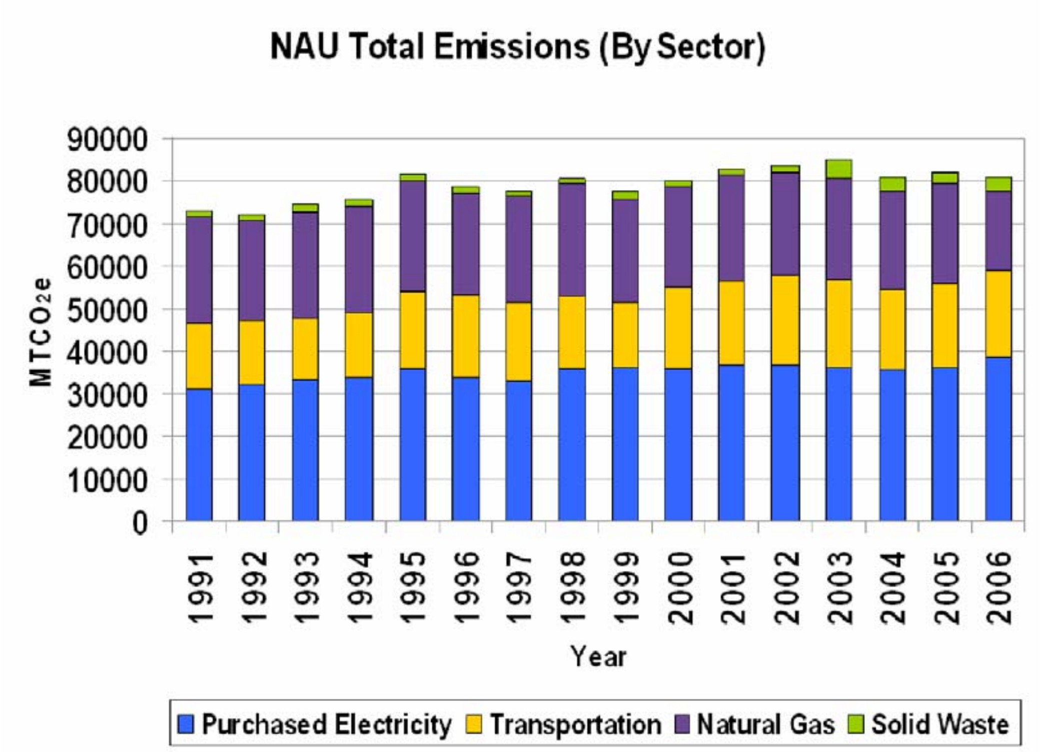

Figure 3: **Sector Contributions (2006)**

Four sources or sectors contribute most to Northern Arizona University's emissions footprint: *electricity*, *natural gas*, *transportation*, and *waste and land management*. The portion of total emissions from each of these sectors is shown in Figure 3. We formed groups to assess possibilities for emissions reductions in each of these four sectors. The projects considered are by no means exhaustive, but do illustrate a broad range of possibilities.

4.1 Electricity

Purchased electricity is the largest contributor to GHG emissions at Northern Arizona University (Figure 3). Electricity emissions were based on the quantity of kilowatt hours (kWh) purchased from APS in each year. The Clean Air Cool Planet calculator converted kWh to $MTCO_2e$ using emissions factors based on estimates by the EPA of power production in the Western Electricity Coordinating Council (WECC) Southwest sector of the United States. In 2006, Northern Arizona University consumed

55,019,821 kWh of electricity which causes emissions of approximately 38,705 $MTCO_2e$. The following are just a few possible emissions reduction projects the electricity team evaluated. These projects are summarized in Table 2.

Table 2: Electricity Reductions Projects

Project	**Net Present Value**	**$MTCO_2e$/Year Reduction**	**$/$MTCO_2e$**
Computer Sleep Mode	$50,210	132	$76.15
Vending Machine Improvements	$11,540	79	$29.19
Photovoltaic Array	-$5,140	0.6	-$873.15

It was clear that some small changes could substantially reduce the electricity emissions of NAU. The most surprising numbers came from factors as simple as computer sleep mode and vending machine power saving strategies. Each of the strategies is explained in more detail below.

4.1.1 Computer Sleep Mode

There are approximately 6000 computers on the NAU campus. Many of these computers are left on when not in use. Although many monitors turn off automatically when not in use, many system boxes do not. The implementation of computer sleep mode over a network can be done by a piece of software called EZ GPO, offered free from the Department of Energy. The electricity group implemented a form of a power management savings calculator[7] in order to target NAU's computer usage specifically.

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[7] http://pmdb.cadmusdev.com/powermanagement/quickCalc.html

Table 3: Sleep Mode Estimations

Capital Cost	\$80
Yearly Cash Flow	\$12,265
Payback Period	Less Than One Year
\$/MTCO$_2$e	\$76.15
Annual Reduction Potential	131.8 $MTCO_2e$
Project Period	5 Years

To calculate the energy savings, a number of assumptions had to be made. These include:

- Electricity cost is \$0.06 per kWh,
- There are 12 hours per work day, 5 work days per week,
- Approximately 30% of the 6000 computers on campus do not use sleep mode on the monitor or system box (1800 total),
- Boxes could be put into sleep mode approximately 40% of the work day,
- Average power usage is 40 watts for a monitor, 57 watts for the system box,[8]
- An initial cost of \$80 is estimated, assuming that it would take 2 workers approximately 4 hours at \$10/hour to implement the system.

This evaluation illustrates the possibility for significant savings from implementing more stringent power saving technologies on computers. A savings of 131 $MTCO_2e$ per year is significant and represents a savings of \$12,265 per year in electricity costs. The project's net present value per $MTCO_2e$ reduced is \$76.15. Additional electricity savings could be obtained simply through further education on computer power management options to students, staff, and faculty. Implementation of these power management strategies, coupled with an education and outreach element should be prioritized, as these efforts would have a significant impact on NAU's carbon dioxide emissions from electricity.

4.1.2 Vending Machine Improvements

Another major contributor to electricity use is vending machines. A company named USA Technologies distributes a piece of equipment called the VendingMiser®.[9] This product reduces a vending machine's (or a bank of vending machines') power consumption in a couple of ways. VendingMiser® uses an infrared sensor in order to power down the

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[8] Many of these numbers were taken from the default settings from the original calculator, or slightly adapted to attempt a more specific fit to NAU.

[9] http://www.usatech.com/energy_management/energy_vm.php

machine when no motion is detected. The machine will also power down for up to three-hour periods, depending on the room temperature, and still keep the products cold.

Table 4: VendingMiser® Estimations

Capital Cost	$18,616
Yearly Cash Flow	$7,354
Payback Period	2.5 Years
$/MTCO$_2$e	$29.19
Annual Reduction Potential	79 $MTCO_2e$
Project Period	5 Years

The possible power savings were estimated using USA Technology's own calculator.[10] This calculator provided us with the data found Table 4. The university currently operates around 104 soda machines on campus. The assumptions made for this calculator are as follows:

- Energy cost is $0.06 per kWh,
- There are approximately 104 soda machines on campus,[11]
- There are 100 operating hours per week (time when the machines are most likely to be operated),
- Soda vending machines consume 400 watts of electricity,
- The VendingMiser® has a sale price of $175 per machine.

This project is another good example of the type of simple, easy-to-implement option that can be undertaken to conserve electricity, (and subsequently greenhouse gas emissions from the production of that electricity). A savings of approximately 79 $MTCO_2e$ is small when compared to total emissions, but the monetary savings of $29 per $MTCO_2e$ in a relatively short period of time is substantial. It should also be noted that the VendingMiser® website claims that APS has a rebate for the purchase of the product, reducing the cost of each from $175 to $75.[12] This would have a significant impact on the initial capital cost of the project and makes this activity even more desirable.

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[10] http://www.usatech.com/energy_management/energy_calculator.php

[11] It should be noted that this evaluation did not include snack vending machines, as data was not obtained for the quantity of these machines on campus; this would most likely also represent a significant savings.

[12] USA Technologies - Energy Management - Rebates and Programs, http://www.usatech.com/energy_management/energy_rebates.php

4.1.3 Photovoltaic Array

The photovoltaic array project involves the installation of a small-scale photovoltaic array on the DuBois Center, in order to mitigate some emissions and provide a test for feasibility.

Table 5: Photovoltaic Array Estimations

Capital Cost	\$3,839
Yearly Cash Flow	-\$185
Payback Period	N/A
\$/MTCO$_2$e	-\$873.15
Annual Reduction Potential	0.59 $MTCO_2e$
Project Period	10

For this estimation the following assumptions were made:

- The array consists of eight donated solar panels, which provide a total power output of 2.5 kWh per day,
- The initial cost of \$3,839 includes installation and all required equipment, as well as the hookup to the power grid,
- A yearly outlay of \$240 assumes 12 man hours of maintenance at \$20 an hour,
- Total energy saved amounts to \$55 a year at a cost of \$0.06 per kWh

4.2 Transportation

4.21 Background

To determine NAU’s transportation related greenhouse gas emissions, we surveyed 1070 students, faculty and staff at NAU. The survey showed that transportation comprises the second largest emissions source at NAU. A large proportion of these emissions come from NAU-related air travel (Figure 1). The group’s efforts focused on finding emissions savings resulting from the implementation of NAU’s current Campus Master Plan, along with a few other easily implemented changes that could significantly reduce emissions, the largest being videoconferencing as a replacement for some faculty travel. While it will be difficult to make transportation carbon neutral, there are changes that could be implemented now to reduce our emissions.

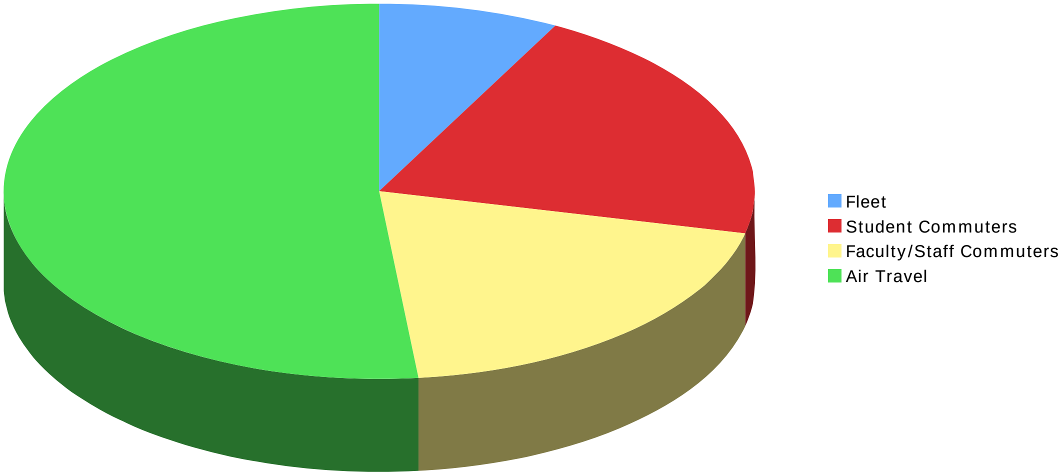

Figure 4 The proportion of NAU's emissions from campus fleet vehicles, student commuting, faculty and staff commuting, and air travel related to NAU business.

The transportation study group only considered those emissions related directly to NAU-related travel: to and from campus commuting, on-campus vehicle travel, NAU fleet vehicles, and NAU business-related travel. We did not include student travel (air or vehicle) for recreation or vacation, transportation emissions from shipping of goods or products such as food, office supplies, etc., or travel to and from airports for faculty and staff trips. These boundaries are very similar to those used in the University of California at Santa Barbara's campus carbon budget.

4.22 Projects proposed by the NAU Campus Master Plan

A series of bold infrastructure changes have been proposed as part of the NAU Campus Master Plan. These include a north-south bus system through the center of campus called a "Spine" system, the replacement of 75% of the existing surface parking lots by a perimeter parking garage system, and the total closure of campus to non-essential vehicles. A series of perimeter roads are planned to remain open. Though these changes were proposed to increase NAU's green space, make the campus more attractive, and decrease congestion, these changes will also reduce greenhouse gas emissions.

The following is an estimation of emissions reductions from the implementation of these measures.

4.221 Bus Spine

The transportation spine is a project outlined in NAU’s Master Plan for a more efficient and reliable bus system. This includes the following:

- Road through campus for the sole use of the spine system buses,
- 7 buses at peak service times, with a peak round trip time of 11 to 12 minutes.

Table 6: **Campus Bus Spine Estimation**

Capital Cost	$10,000,000
Yearly Cash Flow	$10,000
Payback Period	NA
$/MT CO_2e	-$605.07
Annual Reduction Potential	817.6
Project Period	20 Years

The following assumptions were made to estimate the values in Table 6:

- The use of a spine will reduce all on-campus transportation emissions by 10%
- A $10,000 yearly benefit from reduced road repair costs and reduced vehicle maintenance.

The costs were obtained from the NAU Master Plan available at: http://www4.nau.edu/cas/Plan-Dev/Documents/NAU_MasterPlan.pdf.

4.222 Parking Garages

The Master Plan suggests moving parking from surface lots to peripheral deck parking structures. This move will reduce the total acreage deveoted to parking by 75% . There is current demand for 8060 parking spaces on campus. Implementation of the Master Plan would reduce this number by 3950. The construction of parking garages will result in a decrease in to-campus single vehicle commuting due to a decrease in the supply of campus parking.

Table 7: **Parking Garage Estimation**

Capital Cost	$55,300,000
Yearly Cash Flow	-
Payback Period	N/A
$/MT CO_2e	-$3,381
Annual Reduction Potential	817.6
Project Period	20 Years

Assumptions made:

- Each space costs $14,000 (from the NAU master plan)
- The plan will cause a 10% reduction in on-campus transportation emissions, as students would be assigned to only one structure.
- The plan will cause a 25% reduction in commuting, because of fewer existing parking spaces, encouraging people to use alternative transport.

4.223 Closed Campus

After moving all the parking to peripheral lots and constructing a more efficient bus system, implementing a 24-hour closure of campus roads to non-essential vehicles will reduce road upkeep costs and make the campus safer for multi-modal transportation. The campus closure will reduce driving between buildings on campus.

Table 8: **Closed Campus Estimation**

Capital Cost	$100,000
Yearly Cash Flow	$10,000
Payback Period	10 Years
$/MT CO_2e	$0.10
Annual Reduction Potential	2861.6
Project Period	20 Years

Assumptions:

- $100,000 for gate installation and road removal,
- 10,000 savings on road upkeep per year, similar to that of the spine.
- 35% reduction in commuter emissions.

4.23 Changes to Parking Services

- Changes to parking services were evaluated with regards to their cost/savings and emissions reduction potential. These changes include:

- A name change to *"Commuter Services*," in order to emphasize the alternative transportation opportunities to get to NAU
- A 20% increase in permit fees and parking fines, to encourage alternative means of transportation to and on campus
- Education on the health, environmental, and financial benefits of these alternatives

Table 9: Changes To Parking Services Estimation

Capital Cost	$10,000
Yearly Cash Flow	$166,333
Payback Period	Less Than One Year
$/MT CO$_2$e	$354.16
Annual Reduction Potential	327
Project Period	10 Years

The assumptions used to make these evaluations are:

- The initial capital cost of $10,000 includes changes to letterhead and the like, as well as publicizing the changes,
- A yearly outlay for a possible annual cost of the new policies is more than offset by a yearly benefit from increased revenue from permits and tickets,
- It is assumed that these changes will reduce total transportation emissions by 4%.

4.24 Videoconferencing Facility

Mandatory faculty and staff videoconferencing will save NAU millions of dollars and reduce our transportation related GHG emissions more than any other proposed transportation project. While not all conferences offer this service, many do, and so we assume that making videoconferencing mandatory will reduce air travel by 20%. We assume that NAU spends $1000 dollars per person, per trip on airfare, lodging, and food. Reducing this expense can save NAU millions. The $30,000 capital cost was taken from the UC Santa Barbara report on GHG emission mitigation strategies as a cost of a good videoconferencing facility. While likely not a popular option with those who like to travel, videoconferencing is financially and environmentally beneficial, and saves travelers time.

Table 10: Video Conferencing Facility Estimation

Capital Cost	$30,000
Yearly Cash Flow	$1,099,500
Payback Period	Less Than One Year
$/MT CO$_2$e	$369.76

Annual Reduction Potential	2080.4
Project Period	10 Years

4.25 Improved Bicycle Infrastructure

This project includes adopting a “yellow bike” program used in many cities and universities around the country and installing bike lockers in order to promote bicycle use to the university and between locations on campus. Bike lockers are weatherproof storage facilities that enable a bike to be securely protected from vandalism, theft, or weather. At other universities, improving bike storage facilities and bike availability has decreased single-vehicle commuting up to 2%.

Table 11: Bicycle Infrastructure Estimation

Capital Cost	$21,650.00
Yearly Cash Flow	$7,700.00
Payback Period	2.8 Years
$/MT CO_2e	$19.83
Annual Reduction Potential	163.5
Project Period	10 Years

This project makes the following assumptions:

- A 2% reduction in transportation emissions from the project
- An initial capital cost of $21,650 to put the infrastructure in place, based on prices for bike lockers and utility bikes for rental
- A $300 yearly outlay for maintenance (labor not included)
- An $8,000 yearly benefit from bike locker and yellow bike rentals.

4.26 Biodiesel (B20) In MCT Busses

This project estimates the conversion of six MCT busses to a 20% biodiesel/diesel fuel mixture. Biodiesel is produced from vegetable oil and other processed oils, thus it reduces the amount of fossil fuels consumed. It is currently more expensive than traditional diesel fuel. Conversion of bus fleets to run on biodiesel has been popular in programs around the country, including in the Mountain Line and the City of Flagstaff diesel fleet.

Table 12: Biodiesel In MCT Busses Estimation

Capital Cost	$8,000
Yearly Cash Flow	-$4,250
Payback Period	N/A
$/MT CO_2e	-$31.30
Annual Reduction Potential	69.8
Project Period	10 Years

The estimates shown in Table 12 make the following assumptions:

- Conversion cost per vehicle is $1300
- The cost of biodiesel fuel is approximately 6.4% higher than normal diesel

It is also important to note that future bus purchases would need no conversion in order to use biodiesel, so use of this project could be continued in the future without the additional conversion cost.

4.3 Natural Gas

4.31 Background

Northern Arizona University (NAU) uses natural gas primarily for heating. There are sixty-three buildings that are connected to two gas-fired, central heating plants: the North Campus steam plant and the South campus high temperature hot water plant. Additionally, there are thirty-four buildings that independently use natural gas for their heating systems. Dining Services cook stoves and laboratory activities on campus also consume natural gas. In 2006, natural gas consumption emitted 18,557 $MTCO_2e$ accounting for 22.9 percent of NAU's total carbon emissions.

The natural gas team focused its analysis on heating systems at NAU's Flagstaff campus. It did not consider natural gas consumption from heat stoves or laboratory uses. It did not consider natural gas that might be consumed by students and faculty off campus. Most of the options considered by the natural gas team considered changes to the central heating systems and their respective buildings. Some of these mitigation strategies can also be implemented in buildings not connected to the North and South central plants.

4.32. Mitigation Options

The natural gas group focused their analysis efforts on two main strategies: The first examined simple, low-cost policies geared towards conserving heat energy on campus. The second strategy identified improvement areas within NAU's central heating systems that would result in large heating efficiency gains. Table 13 describes a few of the mitigation options considered by the natural gas team.

Table 13 Mitigation options for the Natural Gas Sector

Project	NPV	$MTCO_2e$/Year	$/$MTCO_2e$
Winter Building Temperature	$750,372	904	$83.01
Classroom Consolidation	$97,081	89	$109.43
Energy Management System	$2,916,591	2,674	$72.70
Base Load Boiler	$4,162,418	3,252	$42.67
Rec Center Heating Retrofit	$1,355,776	267	$169.27

These options are described in greater detail below. The following apply to the calculations used in all options.

- All options estimated natural gas savings in units of therms.
- Therms were converted to $MTCO_2e$ using the relationship of 190 therms/$MTCO_2e$.[13]All calculations assumed a natural gas cost of $0.82 per therm. This value was obtained by averaging the cost per therm paid by NAU over the past 3 years (2004-2006).[14]
- Six key metrics are reported for each project: capital cost of project, yearly cost, payback period, annual reduction potential in $MTCO_2e$, dollars saved (or cost) per $MTCO_2e$, and duration of project period.

4.321 Winter Building Temperatures

During the winter, NAU Facilities Management estimates that building temperatures are set at an average of 73 degrees Fahrenheit[15] Most of the heat load required for heating campus buildings occurs during the winter. By lowering winter building temperatures to 68°F from 73°F during the winter, NAU could reduce its natural gas consumption substantially and reduce its carbon emissions from natural gas. Key metrics are listed in Table 14.

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[13] Calculated from values reported in Clean Air Cool Planet.

[14] Gas prices paid by NAU were obtained from NAU Facilities GASREP Worksheet, Schwimmer. C. (n.d.) GAS REP: Gas Usage for Northern Arizona University. Flagstaff, AZ; The choice of averaging over a period of three years is considered to be an accurate estimate of gas prices, this method is also used by GLHN Architectural Associates in the Campus Utility Master Plan.

[15] Interview with Mark Flynn, Director of NAU Capital Assets and Services, April 12, 2007

Table 14 Winter Building Temperature Key Metrics

Capital Cost	$0
Yearly cost	$34,000
Payback Period	less than 1 year
Annual Reduction Potential	904 MTCO2e
$/MTCO2e	83.01 (savings)
Project Period	10 Years

Calculations and assumptions

Energy savings were calculated using a heating degree day (HDD) factor. A heating degree day is calculated by first averaging a particular day's high and low temperatures. If the average is below 65, the number heating degrees for that particular day is calculated by subtracting the average from 65. If that value is above 65, it is not considered a heating degree day.[16] HDD data for Flagstaff, AZ were obtained from the National Weather Services Climate Prediction Center.[17] We then calculated the amount of natural gas that could be saved by lowering winter building temperature by five degrees Fahrenheit. Calculation steps for the heating degree day factor are as follows:

1. The number of HDD's in Flagstaff occurring during the months of September through October is averaged from 1961-1990 (Northeast Regional Climate Center, see footnote 5).
2. Building heat loads for all buildings connected to the North and South plants are summed and divided by the average HDD value from step 1.[18]
3. The HDD factor was calculated by dividing 73 F by the value from step 2, resulting in a HDD factor for these buildings of 5.37 therms /HDD per one degree temperature change.

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[16] NOVITHERM CANADA Inc. (n.d.), Novitherm Heat Reflectors: Calculating Savings. Retrieved April 17, 2004, from http://www.novitherm.com/calc.htm

[17] National Weather Service Climate Predication Center. (n.d.). Heating Degree Day Monthly Summary: Climate Prediction Center-NCEP-NWS-NOAA. Retrieved April 17, 2003, from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/degree_days/mctyhddy.txt; see also The Northeast Regional Climate Center, "Normal Heating Degree Days." http://www.nrcc.cornell.edu/ccd/nrmhdd.html.

[18] Building heat load data obtained from NAU Facilities Management Building Report, 2001. Huggard. S. (n.d.), Former CAS employee, Building Envelope Data: Building Heating Loads. Flagstaff, AZ.

The following assumptions were made in this calculation.

- Heating degree factor of 5.3697 therms/heating degree day
- Buildings 11, 17, 81 and 91 are not included in the data – we did not have heat load data for those buildings
- Building heat load contribution occurs during September – April
- Building baseline temperature during normal winter operating hours is 73°F.
- An education/outreach person is necessary for ensuring policy implementation. This results in a yearly outlay of $34,000.

4.322. Classroom Consolidation

Consolidating night classes in buildings that are more energy efficient during the winter and implementing night-time setbacks in older buildings will also have a substantial impact in mitigating carbon emissions from natural gas. Nighttime setbacks are a no-cost option that allows for immediate carbon savings. Key project metrics are listed in Table 15:

Table 15 Classroom Consolidation Key Metrics

Capital Cost	$0
Yearly cost	$0
Payback Period	Immediate
Annual Reduction Potential	89 MTCO2e
$/MTCO2e	109.43 (savings)
Project Period	10

Calculations and Assumptions

Energy savings were calculated using building heat loads for 6 campus buildings thought to have a redundant night-time function. Thirty-three percent of the energy savings in therms were used to calculate the potential carbon savings. It was assumed that setbacks would only occur one third of the time during the winter (e.g. 8:00 PM to 6:00 AM).

The following assumptions were made in this calculation:

- Night classes from the following buildings can be moved to more efficient buildings: 18, 19, 20, 21, 26, and 65 and these buildings can have night-time setbacks to 65°F from 73°F.
- Night-time setbacks were calculated by using a heating degree day factor of 0.329 therms/HDD.
- We assumed that 33% of the building's annual heat load would be offset for days between the months of September-April.

4.323. Energy Management System

An energy management system would provide a centralized monitoring and control network for NAU to optimize operations of end-use equipment. An EMS could result in large energy savings by providing the ability to monitor, analyze and control the facilities building systems and equipment to achieve energy efficient operation. Additionally, an EMS will easily allow for the implementation of the low-cost options as NAU could control building-level temperature, program night-time setbacks and temperature reductions, and monitor building-level energy use to identify energy savings progress and opportunities.

Table 16 Energy Management System Key Metrics

Capital Cost	$468,600
Yearly cost	$45,000
Payback Period	1 Year
Annual Reduction Potential	2,674
$/MTCO2e	116.50 (savings)
Project Period	15 Years

Calculations and Assumptions

Energy savings were estimated by assuming a 15 percent reduction in the amount of natural gas burned by the North and South central plants from the past three years. Throughout instrumented buildings, the EMS would involve installing "points", which are "controllers or sensor signals" that collect and report the data necessary for automated energy management. The number of points was estimated by assuming that six points per building would be installed, points would be installed at pipe junctions serving two or more buildings, and points would be installed at each of the central plants.[19] The capital cost per point is estimated to be $1100.[20]

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[19] Pipe junctions were determined from the Campus Utility Master Plan: GLHN ARCHITECTS & ENGINEERS INC. (n.d.). 2003. Northern Arizona University Utility Master Plan. Tucson, AZ.

[20] Energy Efficiency and Demand Analysis Division of the California Energy Commision, (n.d.), Technical Options Guidebook. Energy Management Systems. 24-39. Retrieved Febuary 11, 2007, from http://www.energy.ca.gov/enhancedautomation/documents/400-02-005F_TECH_OPTIONS.PDF

The following assumptions were made for these calculations:

- EMS with 426 points installed in heating networks of North and South heating plants at a cost of $1100 per point.
- $45,000 will be needed per year to fund a salaried position for maintaining the network.
- Natural Gas savings of 15 percent, calculated a 15% reduction from the average therms burned from last 3 years (2004-2006) from North and South plants.

4.324 Baseload Boiler

Upgrades to the North Steam Plant can also result in large GHG reductions. Currently older gas-fired boilers at the North Steam Plant operate at 64 percent efficiency. Replacing two boilers that operate at 64 percent efficiency with one base load boiler operating at 85 percent efficiency will result in a 24.7 percent savings of natural gas consumption.

Table 17 **Baseload Boiler Key Metrics**

Capital Cost	$2,000,000
Yearly cost	$10,000
Payback Period	4 Years
Annual Reduction Potential	3,252
$/MTCO2e	42.67 (savings)
Project Period	30 Years

Calculations and Assumptions

Efficiency savings were calculated by first dividing the efficiency of the existing system by the anticipated efficiency of the new boiler. This value was then multiplied by the current natural gas consumption in therms to obtain the amount of natural gas saved per year. The capital costs for this project were estimated to be $2,000,000.[21]

The following assumptions were made in this calculation:

- Calculated current natural gas consumption of North Plant by averaging past three years of natural gas consumption (2004-2006).[22]

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[21] Conversation with Mark Flynn, Director of NAU Capital Assets and Services, April 12, 2007.

[22] Natural gas consumption data obtained from the NAU Facilities GASREP worksheet: Schwimmer. C. (n.d.) 2006, GAS REP: Gas Usage for Northern Arizona University. Flagstaff, AZ

- Boilers 2 and 3 currently operate at 64 percent efficiency. New base load boiler will have an efficiency of around 85 percent. Using the calculation above, we estimate that this will result in a 24.7 percent reduction in the amount of natural gas burned.[23]

4.325. Rec Center Heating Retrofit

NAU Capital Assets and Services recommended that large efficiency savings could occur if the Rec Center, building 25, were connected to the North Steam Plant.[24] The existing heating system would be replaced by a central plant and result in efficiency increases. This option would involve the installation of 1500 ft of 6 inch natural gas piping from the 10 inch main line and the purchase and installation of a shell and tube heat exchanger. Table 6 describes the key metrics for this option.

Table 18 Rec Center Heating Retrofit Key Metrics

Capital Cost	$750,000
Yearly cost	$2,000
Payback Period	15 Years
Annual Reduction Potential	267 $MTCO_2e$
$/MTCO2e	$169.27
Project Period	30 Years

Calculations and Assumptions

Energy savings calculations were performed using eQUEST, a Building Energy Simulation Tool offered by the Department of Energy, free of charge.[25] A number of assumptions about Rec Center building usage and operating hours were entered into the program. Gas consumption data was obtained from the NAU Facilities GASREP worksheet.

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[23] Equation for calculation was obtained from: Borman, G., Ragland, K., (1998). Combustion Engineering. United States: McGraw-Hill.

[24] Carson Pete's meeting with Joshua Spears and Mark Flynn, April 2, 2007.

[25] Hirsch, J., (1998). eQUEST: the Quick Energy Simuation Tool. Retrieved March 15, 2007. from http://www.doe2.com/equest/

The following assumptions are made for these calculations:

- Building Use: Of the total building space, 77% is for exercise and gymnasium, 7% for restrooms and lockers, 8% for corridors, and 3% for storage and mechanical rooms.
- Operating temperature – 72º F
- Operation hours: Mon/ Tues /Wed / Thur– 6am to 11pm, Fri- 6am to 9pm, Sat / Sun- 11am to 9pm
- Boiler Efficiency: package boilers now in use, 55%, North plant steam, 64%
- Heating begins one hour before building opens and ends one hour after building closes
- Building operations are conducted throughout the entire year except for normal holidays
- Season weather data was correct on the program for Flagstaff, AZ
- Capital cost estimation to be between $500,000 – $1,000,000, assuming that would cover the cost to lay 1500 ft of 6 inch piping to the rec center from the 10 inch main line, the cost to buy a shell and heat tube exchanger, cost to install total unit.

4.33 Additional Recommendations and Considerations

The natural gas team also examined a number of potential energy savings opportunities. Energy savings and GHG reduction potential have not yet been calculated for many of these options, but the following strategies should also be examined by NAU for their GHG reduction potentials. The following options and their data requirements are described.

4.331 Building-level HVAC retrofits

Upgrades to building-level HVAC systems could improve the way that air moves through a building, allow for programmable temperature fluctuations, and reduce energy costs by circulating building air only when it is necessary. For example, replacing worn out heating systems in older buildings with variable air volume boxes would allow for better control of air flow. Initial investigations into this option reveal that energy savings occur for both electricity and natural gas sectors. A cost estimate for this option can be calculated from a price of $10-12 per square foot.[26] This estimate includes costs for new VAV boxes, ductwork for air distribution, piping for reheat coils, and controls. In order to calculate energy savings,

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[26] Cost estimates obtained from Kevin Dominick, Professional Engineer, DS Engineering Inc. Escondido, California, Kevin@dsemec.com, April 27, 2007.

an inventory of all existing heating systems on campus should be performed and current system efficiencies noted.

4.332 Variable Speed Drive installation on South Plant HTHW distribution pumps.

Installing variable speed drives on the South plant’s distribution and re-circulating pumps can result in energy savings by allowing the pump motor speed to respond to heat load demand. Instead of operating at one speed, the pump would only use the required voltage to drive the motor. Energy savings are realized in decreased electricity consumption from pump motors. Initial costs for installation of pumps can be calculated by estimating a cost of $15,000 per 40 HP pump and $10,000 for each 25 HP pump. The cost includes: drive unit, installation, controls, wiring, mark-up and overhead.[27] To calculate energy savings, the fluctuations in building heat load demand on the pumps should be determined. Then savings from slower motor speed during times of low demand can be estimated.

4.333 Two-way valve installation, South Campus HTHW plant

Installing two-way control valves on Shell and Tube heat exchangers that are servicing buildings connected to the South Plant would result in better control of building temperatures and management of building heat loads. The cost for this option could be estimated at $25,000 for 6 inch valves and $45,000 for 10 inch valves.[28] To calculate energy savings, an estimation of building usage and heat load demand should be determined.

4.334 Air Handlers for Large Campus Buildings

Based on conversations with NAU Capital Assets and Services, the installation of new air handler units for the Skydome, the Field House, Ardrey Auditorium, Prochnow Auditorium and the Rolle Activity Center would result in substantial energy savings. Cost estimation for air handling units can be estimated with $8.00 to $10.00 per CFM (cubic feet per minute) or $7.00 per square foot of building space.[29] In order to calculate energy savings and finalize cost estimates, the air flow capacity of each existing air handling unit in the buildings needs to be determined and compared to the air flow capacity of existing systems. Building usage should also be considered.

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[27] *Ibid.*
[28] *Ibid.*
[29] *Ibid.*

4.335 Building Renovations

Improving roof and window insulation in older campus buildings will increase energy efficiency by reducing building-level waste heat. Discussions with NAU's HVAC personnel conclude that this is an area where NAU can significantly enhance its energy savings. In 2006, the Office of Residential Life began upgrading roofing and insulation in campus dorms; they may be a useful source for cost information. To calculate potential energy savings, an inventory of existing window types and insulation materials in all buildings should be performed. This information can be used in a building energy simulation software program, such as eQuest, to estimate energy savings achieved from the installation of newer building materials.

4.4 Waste & Land Management

4.4.1 Waste and Recycling

One way to reduce emissions caused by NAU's solid waste is by increasing recycling. A successful recycling program reduces methane emissions from the landfill, extends the life of the landfill, conserves resources, saves energy, and is an activity in which each of us may easily participate. A recycling program is also a very visible indication of the level of commitment of any group to the reduction of greenhouse gas emissions.

Waste is the smallest contributor of GHG emissions at NAU, contributing 4.4% to the total emissions. With help from the City of Flagstaff, we were able to obtain actual tonnage figures for both waste going to the Cinder Hill Landfill, and recyclables going to the Norton Environmental Materials Recovery Facility (MURF). In 2006, total annual tonnage of waste produced by NAU and going to the landfill was estimated at 1,655 short tons, which causes emissions of 1,638 $MTCO_2e$. Based on a direct waste audit conducted in Spring 2007, of the total tonnage of 1,655, more than half (960 tons) was actually recyclable material. Of the unrecovered recyclables, the highest percentage was paper and cardboard (62%), followed by plastic (22%), aluminum (9%), glass (6%), and tin (1%) At the same time, the total tonnage going to the MURF during was estimated at 683 tons, but with a contamination rate of 35-40 %.

A chart of NAU's tonnage per year of landfill and recycling waste is shown in Figure 5. Since 2000, recycling has decreased significantly while the amount of waste sent to the landfill has increased significantly.

These trends illustrate the importance of a recycling education and outreach program to improve waste management at NAU.

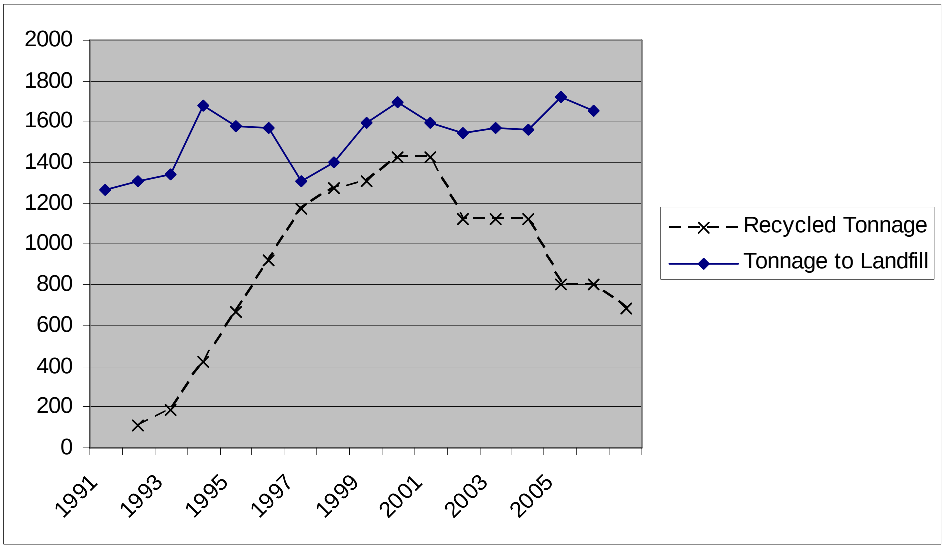

Figure 5 Tonnage Of Recycling & Waste, 1991 To 2006

Clearly, an education and outreach program is needed to increase the amount of recyclable materials going to the Material Recovery Center, to reduce the contamination rate of materials going to the Material Recover Center, and to decrease the amount of recyclables going to the landfill. Some suggestions include:

- A green dumpster and a brown dumpster should be located outside every campus building.
- Containers located inside buildings should be lined with clear, not dark, trash bags
- A student led education and outreach program should be supported and should include:
  Posters educating students and faculty about the campus recycling program,
  A power point presentation accessible to students, faculty and staff
  Educating new students about recycling during orientation with materials given to every student entering campus, and
  Website with recycling information, and container locations on campus.

We estimated reductions in greenhouse gas emissions resulting from this type of program, assuming the program increases recycling by 30% to 50%. The results of these evaluations are shown in Table 19.

Table 19 Recycling Program Estimations

Recycling Increase	**30%**	**50%**
Capital Cost	\$4,000	\$4,000
Yearly Cash Flow	-\$500	-\$500
Payback Period	N/A	N/A
\$/MTCO$_2$e	-\$2.11	-\$1.27
Annual Reduction Potential	270.3	450.5
Project Period	15 Years	15 Years

We assume a \$4,000 initial cost for website design, posters and signs, and a \$500 yearly outlay for student help to distribute them each year.

4.4.2 Forest Sinks

The Kyoto Protocol allows the use of carbon dioxide sinks as a form of carbon offset. Managing NAU's Centennial Forest would serve to reduce CO_2 emissions caused by forest fire, offset emissions by sequestration, and provide fuel for a biomass plant. The Centennial forest lies north of Flagstaff, Arizona, just west of Wupatki National Monument, and southwest of town.[30] Vegetation in the Centennial Forest includes four major terrestrial ecosystems [31]: 5,000 ha [32] of grasslands, 5,300 ha of pinyon-juniper woodlands as well as transition zone forests, 7,200 ha of ponderosa pine and oak forests, which dominate the southwest portion, and over 1,200 ha of wetland-meadow ecosystems. Our analysis assessed the costs and benefits of restoring half of the ponderosa pine forests within the Centennial Forest to the tree densities and fire regime typical of pre-settlement conditions. Such restoration involves thinning to remove small-diameter trees, thereby reducing the risk of catastrophic wildfires and avoiding associated carbon release to the atmosphere.

Table 20 Forest Management Estimations. All values are per hectare.

Capital Cost	\$750
Yearly Cash Flow	\$20
Payback Period	N/A
\$/MTCO$_2$e	\$1.63
Annual Reduction Potential (MTCO$_2$e**)**	3.4
Project Period	40 Years

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[30] http://www.for.nau.edu/CentennialForest/content/view/547/754

[31] http://www.for.nau.edu/CentennialForest/content/view/546/753/

[32] A hectare (ha) is an international unit of measurement for land area which consists of 10,000 m^2, roughly 0.4 acres per hectare (http://www.bipm.org/en/si/si_brochure/chapter4/table6.html)

For these calculations, we assumed that[33]:

- Long-term net ecosystem production is zero for these forests. Emissions occur because of stand-replacing wildfires.

- The probability of stand-replacing wildfire in the absence of any treatment is 0.625 over 40 years. This probability is reduced to 0.0675 after restoration. These are means of best guesses based on discussions with various experts, including Drs. Pete Fule and Alex Finkral.

- Stand-replacing wildfire causes emissions of 3.4 MTCO_2e per hectare per year in the absence of restoration, 0.2 MTCO_2e per hectare per year with restoration. This quantity is calculated as:
  [CO_2 emitted during fire X probability of wildfire]/40 years

- CO_2 emitted during stand-replacing wildfire is calculated assuming that 80% of aboveground and 50% of forest floor carbon is mineralized to CO_2 during fire. This amounts to 230 MTCO_2e for the unrestored condition, and 110 MTCO_2e for the restored condition.

- Unrestored ponderosa pine forests contain 87 metric tons carbon per hectare in the aboveground and forest floor components (319 MTCO_2e). Restoration reduces this quantity to 45 metric tons carbon per hectare (164 MTCO_2e) at a cost of $750 per hectare. Carbon stock data are mean values from restoration experiments in the Gus Pearson Natural Area (Kaye et al. 1999 and Kaye et al. 2005) and Flagstaff Urban-Wildland Interface Experiments (Hart et al. 2006, Hungate et al. 2007).

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[33] References:
Hart SC, Selmants PC, Boyle SI, and Overby ST, 2006. Carbon and nitrogen cycling in southwestern ponderosa pine forests. Forest Science 52:683-693

Hungate BA, Hart SC, Selmants PC, Boyle SI, Gehring CA, 2007. Soil responses to management, increased precipitation, and added nitrogen in ponderosa pine forests. Ecological Applications, in press.

Kaye, J.P., S.C. Hart, P.Z. Fulé, W.W Covington, M.M. Moore, and M.W. Kaye. 2005. Initial carbon, nitrogen, and phosphorus fluxes following ponderosa pine restoration treatments. Ecological Applications **15**:1581-1593.

Kaye, J.P., S.C. Hart, R.C. Cobb, and J.E. Stone. 1999. Water and nutrient outflow following the ecological restoration of a ponderosa pine-bunchgrass ecosystem. Restoration Ecology **7**:252-261.

4.5 Biomass

The natural gas, electricity, and land use teams team worked together to examine the feasibility and carbon savings that would result from installing a 3 MW ChipTek, co-generating biomass plant on South campus. In addition to supplementing NAU's electricity purchases, the plant would serve as a third central heating facility for the following campus buildings: 71, 76, 79, 77, 77A, 80, 83, 84, 98A, 98B, 98C, 98D. This option would replace the need for natural gas heating in these buildings. This plant would also rely on biomass harvested from the NAU-managed Centennial Forest, thereby having the added benefits of reducing wildfire risk and restoring these forests to healthier conditions. The assumptions described above for "Forest Sinks" also apply here.

Producing both heat and electricity would decrease our natural gas and electricity bills and associated greenhouse gas emissions. Implementation of this project would result in the greatest emissions reduction of all the recommended projects (17,681.5 $MTCO_2e$). Feeding the co-generating biomass plant with small diameter trees would serve a dual benefit in reducing and offsetting NAU's GHG emissions.

Current land management initiatives being implemented across public lands in northern Arizona to reduce the risk of catastrophic wildfire generate a sizable quantity of small diameter trees that have relatively little value because of a lack of market. A biomass energy plant would provide a use for these small diameter trees, as well as provide for further fire risk reduction by reducing the number and size of slash piles present on the forest post-harvest. An added benefit of thinning the forest is increased stability of carbon storage. Reducing the risk of stand replacing fire ensures that the stocks of carbon remaining there would stay for a long time, far longer than if they were left in the overgrown state they occur today. In this way, the biomass energy plant would create a land-use offset for some of our carbon emissions. Including the costs to purchase the power plant itself and the annual costs associated with harvesting and preparing the fuels, as well as the energy savings and reduced emissions, this project appears to be economically viable and to take a major slice out of our greenhouse gas footprint. It would represent a substantial step toward carbon neutrality.

We should acknowledge that this approach pushes the boundaries of current carbon offset policies. No policies we've found specifically allow protection from wildfire as a carbon credit. Yet, managing forests to promote carbon storage is a widely accepted approach to reducing carbon emissions. Our carbon protection strategy is the next step in this developing field, and makes sense for fire-prone regions. Furthermore, the project causes substantial emissions reductions even without considering the increase in forest carbon storage. In sum, NAU should seriously consider biomass energy as part of its greenhouse gas management portfolio. Because of the large potential savings and the high capital costs, this option warrants additional research.

Capital Cost	$4,400,000
Yearly Cost	$3,681,799
Yearly RevenuePayback Period	$4,672,6812.77 Years
Payback PeriodAnnual Reduction Potential	4.44 Years17,681.5
Annual Reduction Potential$/MTCO$_2$e	34684$23.68
$/MTCO$_2$e	$23.686.35
Project Period	40 Years

Assumptions:

- We assume the following annual costs:

Yearly Costs[34]	
Restoration (shearing and skidding)	$330,000
Chipping & Transport	$458,798
Ash transport	$7,949
Depreciation	$500,000
Electricity Purchased	$1,419,511
Personnel	$965,541

- We assume the following annual savings and revenues:

Yearly Savings	
Natural Gas Savings	$2,543,413.46
Electricity Sold to APS	$2,129,267.07

- We also assume that NAU will win federal and local grants (e.g., High Desert Investments) to cover $5,600,000 toward purchase of the biomass energy plant

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[34] Estimates based on reports from the GFFP and Bellemont biomass plant plans.

5. Conclusions

The findings of this report point toward a three tiered implementation program. Emissions reducing projects that require little or no capital investment should be implemented immediately. These would include the implementation of the computer sleep mode software, reducing building temperatures in the winter, and nightime classroom consolidation. Implementing tier 1 projects would involve a capital investment of $80.00, reduce annual campus emissions by 1125 $MTCO_2e$, and save the university approximately $300,000/year. The second and third tier projects, moderate and high capital investment projects, should be prioritized based on the $/$MTCO_2e$ metric when feasable. These projects are ranked by $/$MTCO_2e$ in Tables 21 and 22.

Table 21 Tier 2 (moderate capital investment) projects ranked by $/$MTCO_2e$

Project	Capital Investment	MTCO2e/yr reduction	$/MTCO2e
Video Conferencing Facility	$30,000	2080	$369.76
Changes to Parking Services	$10,000	327	$354.16
Rec Center Heating Retrofit	$750,000	267	$169.27
Energy Management System	$468,600	2674	$116.5
Vending Machines	$18,616	79	$29.19
Bicycle Infastructure	$21,650	163.5	$19.83
Closed Campus	$100,000	2862	$0.10
Recycling Program	$4,000	450.5	-$1.27
Biodiesel	$8,000	69.8	-$31.3
Photovoltaic Array	$8,339	0.6	-$873.15

Table 22 Tier 3 (high capital investment) projects ranked by $/$MTCO_2e$

Project	Capital Investment	$MTCO_2e$/yr reduction	$/$MTCO_2e$
Baseload Boiler	$2,000,000	3252	$42.67
Biomass Energy Plant	$4,400,000	34010*	$6.81
Campus Bus Spine	$10,000,000	818	-$605.07
Parking Garages	$55,300,000	818	-$3381

*200 hectares per year

Implementing all of the tier 1 and 2 projects would require a capital outlay of approximately $1.4 million, reduce NAU's annual emmisions by 11,223 $MTCO_2e$, and have a net present value of $690.27 per $MTCO_2e$. This capital investment would reduce NAU's annual emmissions by 14%. Adding the baseload boiler and biomass co-generating facility would result in a total of 40% reduction in GHG emissions. This $7.8 million investement would not only greatly reduce emissions, but would also provide a long-term financial benefit to the University. In addition to implementing the projects listed above, other measures to reduce GHG emissions should be explored in future offerings of this class.