A Sustainable University of Delaware®

CLIMATE ACTION PLAN

Prepared by the Center for Energy and Environmental Policy

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Commitment

In May 2008, the University of Delaware's Strategic Plan, the Path to Prominence™ set a goal of attaining carbon-neutrality. This strategic decision was formally reinforced by President Harker's decision to sign the American College and University Presidents Climate Commitment. The message to our community through these actions is clear: as a community and an institution, we must creatively and energetically reexamine our habits, policies and daily practices to reduce the University community's collective impact on the planet.

Reducing carbon emissions requires tapping into the intellect, passion and resources of our campus. With input from across our community and our senior leadership, and with the Senior Class Gift of 2008 to spur action, the Carbon Footprint Initiative (CFI) was launched. The CFI' first step was to build an accurate inventory that would raise awareness about the University's collective impact on greenhouse gas emissions.[1] The second step was the development of a University Climate Action Plan to reduce carbon emissions.

The purpose of the University's first Climate Action Plan is to identify a path towards reaching the University's aggressive environmental goals**.** The University's first CAP is a 10-year Plan which will reduce campus emissions by at least 5% by 2013, 10% by 2015 and 20% by 2020. If the University continues this process, it can reach the long-term goal of carbon neutrality by mid-century.

Like all forward-looking strategies, this Plan is a living document with an expectation that changes will be made as new opportunities and technologies arise. Although projects may be added or revised, what will not change is the University's commitment to reduce its carbon emissions. Under the Presidents Climate Commitment, the University of Delaware has pledged to update its greenhouse gas inventory and action plan every three years in order to realize an ongoing commitment to achieve carbon-neutrality.

Engaging the Community

This plan could not have been assembled without the assistance and input of the University community. The development of the University's first Climate Action Plan was guided by an Advisory Committee composed of a cross-section of our community as well as the principles set forth in the University's Strategic Plan and the University Capacity and Campus Assessment Review. A comprehensive outreach process to all members of the University community was completed to canvass ideas about opportunities for significantly changing the University's carbon footprint.

[1] See http://www.udel.edu/sustainability/footprint/.

On November 16, 2008 the outreach campaign was initiated with a University Town Hall where Dr. John Byrne, Director, Center for Energy and Environmental Policy (CEEP) and Distinguished Professor of Public Policy shared the preliminary carbon inventory findings. An online video of the event was posted on the University's website and a permanent email account (carbonfootprint@udel.edu) was created for receiving feedback. In February and March, Dr. Byrne held additional town halls at each College outlining a draft action plan. Dr. Byrne also held a town hall with student organization leaders to ensure student feedback. Sessions at dormitory complexes were conducted by Drew Knab (Project Analyst, Office of Executive Vice President and University Treasurer) and extensive meetings were held with staff of the University's Facilities, Dining Services, Public Safety, Procurement and Landscaping units. Nearly 500 members attended the town halls, and hundreds of ideas were proposed through the email portal and at the town halls. The enthusiasm and innovative thinking of our community is heartening. We cannot realize a carbon-neutral future unless <u>all</u> members of the University are engaged.

Process and Participation

From the announcement of the Carbon Footprint Initiative by President Harker on April 10, 2008 to the release of the University's first-ever Climate Action Plan on Earth Day 2009, a comprehensive approach to engaging the community was pursued. The Class of 2008's decision to fund the development of a university-wide climate action plan as their senior class gift enabled the Carbon Footprint project to conduct the necessary research, to hold numerous feedback sessions with academic and administrative departments across campus.

In order to develop a comprehensive carbon inventory and climate action plan, a Carbon Footprint Research Team, Working Group and Advisory Committee were formed. The research Team was led by Drs. Byrne and Lado Kurdgelashvili (Research Fellow, CEEP) and included graduate students with backgrounds in electrical, mechanical, civil and environmental engineering, economics, and energy and environmental policy. The working group was represented by eight individuals whose administrative units play a central role in the primary area of emissions. The working group was charged with providing critical data and perspective in the development of the University's carbon inventory. In addition to the working group, an Advisory Committee was charged with determining the emission reduction strategy and identifying funding mechanisms. This group was represented by senior academic and administrative officials, external experts, as well as student leadership. Please see Appendix 1 for a list of research team members and advisory and working group members. A total of 14 campus units contributed to the development of the Carbon Inventory and Action Plan. In addition, the deans of all seven Colleges, student government leaders, and unit directors from across the campus collaborated in the organization and implementation of the outreach campaign so that all community members could contribute to the planning process.

Since its formation in April 2008 through March 2009, the Advisory Committee met on five official occasions to review the work completed by the working group research team. In June 2008, the Advisory Committee outlined the priorities for development of an Action Plan and provided initial direction on how the Inventory would be developed. From June to August 2008, the research team collected data to determine the amount of emissions caused by university buildings, transportation, waste, landscaping and dining services.

During summer 2008, student researchers from CEEP and the College of Engineering, under the direction of the University's Industrial Assessment Center co-director Ralph Nigro, completed building audits of 16 representative campus buildings and all six university utility plants. In September 2008, the Center for Energy and Environmental Policy presented the initial inventory findings to the Advisory Committee. At this meeting, the Advisory Committee developed criteria to assess proposed greenhouse gas mitigation strategies and also began organizing a campus town hall to present the Inventory results to the community. On November 18, 2008 a Carbon Footprint Town Hall meeting was held in Mitchell Hall. This event enabled the community to learn the factors driving University emissions and solicited ideas for the development of the University Action Plan. The event was webcast live and a podcast was placed on the University's Carbon Footprint website to ensure all university community members could comment.

Throughout November and December 2008, CEEP analyzed potential emission reduction strategies, reviewed best practices at peer institutions, and evaluated proposals from the community. In January 2009, CEEP delivered a draft Action Plan for the Advisory Committee to review. After incorporating changes, the Advisory Committee then recommended that CEEP hold feedback sessions on the Action Plan at every College and residence hall complex and with the student government.

Throughout February and March 2009, Dr. John Byrne and CEEP researchers held Climate Action Plan Town Halls at the College of Agriculture and Natural Resources, the College of Engineering, the College of Arts and Sciences, the College of Human Services, the College of Health Sciences, and the College of Marine and Earth Studies. A student government Town Hall was held in Febraury 2009 at Trabant University Center to encourage student organizations and leaders to provide recommendations to the Plan. Furthermore, feedback sessions were held at each dorm complex on campus so that all students could easily join in the conversation over how to reduce carbon emissions.

This Plan could not have been assembled without the assistance and input of the University community. The University's first Climate Action Plan reflects our community's ideas, values and desire for change.

Categories for Action

The Climate Action Plan is organized around four categories for action: Green Infrastructure, Green Power, Sustainable Transport and Green Community Action. A brief description of each category is provided below.

Green Infrastructure: Invest in Energy Efficiency, Metering, and Building Automation Systems

Approximately 76% (116,000 $MTCO_2$) of the total University emissions stem from building operations. In order to reduce building energy usage, the University must invest in energy efficiency upgrades to HVAC systems, implement lighting retrofits and improve monitoring and metering of campus buildings. The University must also expand upon existing building automation systems to efficiently manage building energy levels. Replacement of aging infrastructure, such as steam lines is needed. Finally, the University needs to establish an environmental standard for new construction and for retrofits of the existing building stock that lowers energy requirements and carbon emissions sufficiently to meet LEED Silver criteria.[2]

Green Power: Transition to a Clean Energy Future

Investments in energy efficiency will decrease energy usage. However, buildings will always require a baseline amount of energy. For the University to dramatically reduce carbon emissions, it will have to also increase its use of clean forms of energy including cogeneration plants, renewable energy, and other innovative solutions such as fuel cells. The Plan sets a target of 10% of 2008 electricity use provided by clean energy supply by 2013 and 20% by 2020 (including the University's participation in the City of Newark's offshore wind purchase). Clean energy supply includes: a proposed combined heat and power plant; use of geothermal heat pumps; a fuel cell power facility; participation in the offshore wind purchase by the City of Newark; and a major effort to utilize solar electric power. The University is honored to be the U.S. Department of Energy's "Center of Excellence in Solar Electricity R&D." Campus use of this technology demonstrates the University's commitment to research, education and environmental leadership in renewable energy.

Sustainable Transport: Implement Alternative Transportation Strategies

Similar to the State of Delaware, the University community overwhelmingly uses the automobile for their primary means of transport. This translates into significant emissions. Moving the university in the direction of more responsible forms of transportation requires adding incentives for ridesharing and alternative modes,

[2] "LEED" stands for the Leadership in Energy and Environmental Design. This rating system for building ecological performance was created by the U.S. Green Buildings Council. The LEED ratings cover four categories: Platinum, Gold, Silver, and Certified. The highest awarded rating is LEED Platinum for scores between 52-69; LEED Gold is awarded for a score of 39 to 51; a LEED Silver rating is given for buildings that score between 33-38, and LEED Certified is awarded for scores of 26 to 32.

developing the physical infrastructure required to support alternative modes, and expanding the university's bus system.

Green Community Action: Actively promote an ethic of environmental responsibility

Without an engaged and committed university community, the University will not reach carbon neutrality. The Office of Resident Life in conjunction with the Academic Affairs and Student Life Sustainability Task Force will institute a green dorm certification. A green liaison program will be established on a volunteer basis allowing individuals across campus to become a university green liaison. Green Liaisons will serve as an information channel of environmental information and identify improvements in their units.

Inventory Overview[3]

The University of Delaware's total emissions are estimated to be 152,542 $MTCO_2$ for the 2007-08 academic year (see Figure 1). This amounts to 8.7 $MTCO_2$ per student and 7.1 $MTCO_2$ per University community member (faculty, staff, and students). The University has committed to reducing its emissions, and the purpose of this proposal is to introduce options that will allow the University to meet that commitment.

Emissions from activities related to the operation of buildings and the activities conducted within them are the primary source of University CO_2 emissions. Unsurprisingly, the largest share of emissions reductions in the University's Climate Action Plan come from this category as well. Building emissions at the University of Delaware are a result of many different processes and powered by burning a variety of carbon based fossil fuels. Currently, space heating and water heating are the result of the burning of natural gas and residual fuel oil. Centralized chilled water plants, air handling units, pumps and fans that circulate water and air, appliances, electrical equipment, computing devices, and lights are powered by electricity. GHGs are emitted as a result of turning fossil fuels into heat and electricity in all of these processes. The inventory portion of the carbon footprint project revealed opportunities for improving energy use practices and technology at the University. Some of the more substantial observations that the action plan seeks to address are:

- Lighting

  Although lighting efficiency has been generally addressed, there are additional opportunities to reduce energy use in this area. Occupancy sensors should be installed in intermittently used areas such as restrooms and lounges, areas with excessive lighting should be de-lamped, and natural daylight should be used when possible.

[3] A separate report detailing the University's Carbon Inventory for the Newark campus is available online at http://www.udel.edu/sustainability/footprint/. As background to the Action Plan, the Inventory is briefly summarized here.

- Motor Technologies

  Motors are used to circulate hot and cold water, and air. Although variable speed drives, that match demand with circulation, thereby reduce waste, have been installed on some pumps and fans, additional opportunities for installation exist.

- Information Management

  In order to make decisions and detect trends that could assist facilities management in reducing energy use, information systems should be installed that meter energy use on a building level.

- Utility Plant Equipment

  Utility plants supply steam, hot water and chilled water to buildings on campus. The age, condition, and efficiency of boilers, chillers and auxiliary equipment within these utility plants vary. Although equipment is generally in good condition, many opportunities remain to increase production efficiency.

The Action Plan addresses the building-related findings above and recommends best practices that can be used to reduce the University's energy use.

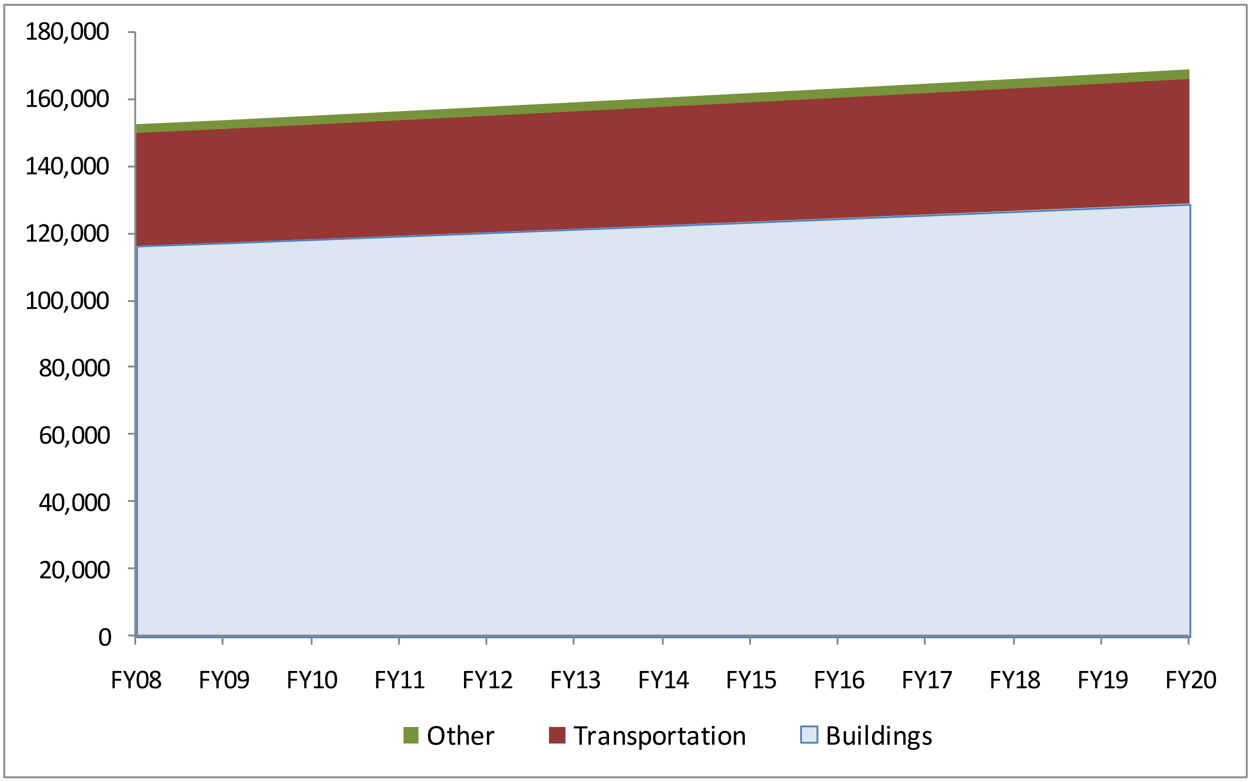
The second largest share of total University emissions stems from transportation related emissions. Transportation emissions are caused by the burning of fossil fuel consumed by the vehicle fleet as well as from campus community members commuting to and from the University using their own means of transportation. The GHG inventory revealed opportunities to reduce these emissions through increasing the efficiency of the University fleet and implementing alternative transportation programs for commuters.

Although emissions from waste generated by campus activities are a relatively small percent of total emissions, reductions projects within this category were deemed important due to their ability to promote participation from the entire campus community. Recycling, for example, will require the participation of all members of the campus community. Additional details on the University's greenhouse gas emissions are available in the Greenhouse Gas Inventory report on the University's Carbon Footprint Initiative website: www.udel.edu/footprint.

Business as Usual Emissions

Based on current emissions trends, if the University were to take no action, emissions would increase by 10.7% by 2020 (using the 2007-2008 academic year as a baseline) (see Figure 1). Although this increase may not seem astonishing, if the goal is to play a part in slowing and eventually reversing climate change, any increase in emissions, no matter what the scale, is unacceptable.

Figure 1: Business as Usual Emission Trend



Overview of the Action Plan

Within the inventory categories of Buildings, Transportation, or Waste, there are three basic tools that can be utilized to achieve emission reductions: Efficiency, Conservation and Clean Energy. The projects presented within this report all fall within one of these three categories.

A Phased Approach

Using the results of the inventory and building audits, as well as input from the campus community, the Carbon Footprint Advisory Committee, Research Team, and Facilities Department, worked together on the development of a detailed Action Plan comprised of a portfolio of initiatives that will ultimately result in the University meeting significant carbon reduction goals. The Action Plan reflects a phased approach, and includes initiatives that will be implemented in 3-year, 5-year, and 10-year timeframes. The timeframe for each initiative depends primarily on its scale, cost, economic and carbon impact. Phase I of the Action Plan includes projects that will be completed within three years. Implementation of several of these projects is already scheduled (see below).

The Phase II or 5-year plan adds priority projects that, along with the Phase I initiatives will enable the University to lower its projected energy costs by more than 30%. A portion of these savings will be applied to projects in the Phase III Plan. Several of these projects, such as a fuel cell power plant, are expensive and will require additional revenue sources to complete. The 10-year target sets the University of Delaware on a course to reduce carbon emissions by more than 20%[4].

Selection Criteria

Project ideas contained within this proposal came from a variety of sources including the campus community, peer institutions, the State of Delaware's carbon reduction action plan[5], and other resources.

In order to compare the list of potential projects several criteria were used. Projects were evaluated based on the extent to which they could reduce the University's GHG emissions, but this criterion was not the only one considered. Carbon reduction capability was balanced against other factors including cost-effectiveness and technical feasibility. In addition, projects were also assessed by their ability to engage our community and to challenge it. As an educational and research institution, our University should be able to embrace the Carbon Footprint Initiative as an opportunity to demonstrate the value of research and education in the global climate crisis.

Two characteristics of each project were quantified: (1.) the amount of time it would take for the University to recover the costs of the investment based on the energy savings associated with the project – or payback; and (2.) the cost of the investment per metric ton of carbon emissions avoided. A 6% discount rate was used in calculating cost per metric ton. Projects which had a payback of more than ten years were given low priority unless they could be justified due to significant strengths in another area. For example, it is difficult to project the quantitative impact of a Green Liaison Program (described below), but the educational benefits of such a program are undeniable and it would be inappropriate for a University Plan to proceed without trying to improve community awareness. Carbon reduction from projects that have a payback of ten years or less is more than 28%. The total potential for Carbon reduction, including those initiatives with larger paybacks or economic impacts that are hard to measure, is over 35%.

The carbon abatement cost curve is a visual representation of GHG abatement projects and their relative cost of reduction in dollars per unit of CO_2 equivalent. Figure 3 includes projects evaluated to date. Certainly, more can be done and the Action Plan should be treated as a "living document" continuously updated to reflect new opportunities and new technology.

[4] The University of Delaware 10-year target is met by direct campus reduction without resort to offset.
[5] See http://ceep.udel.edu/publications/energy/reports/energy_delaware_climate_change_action_plan/deccap.htm

Figure 2: Payback Chart

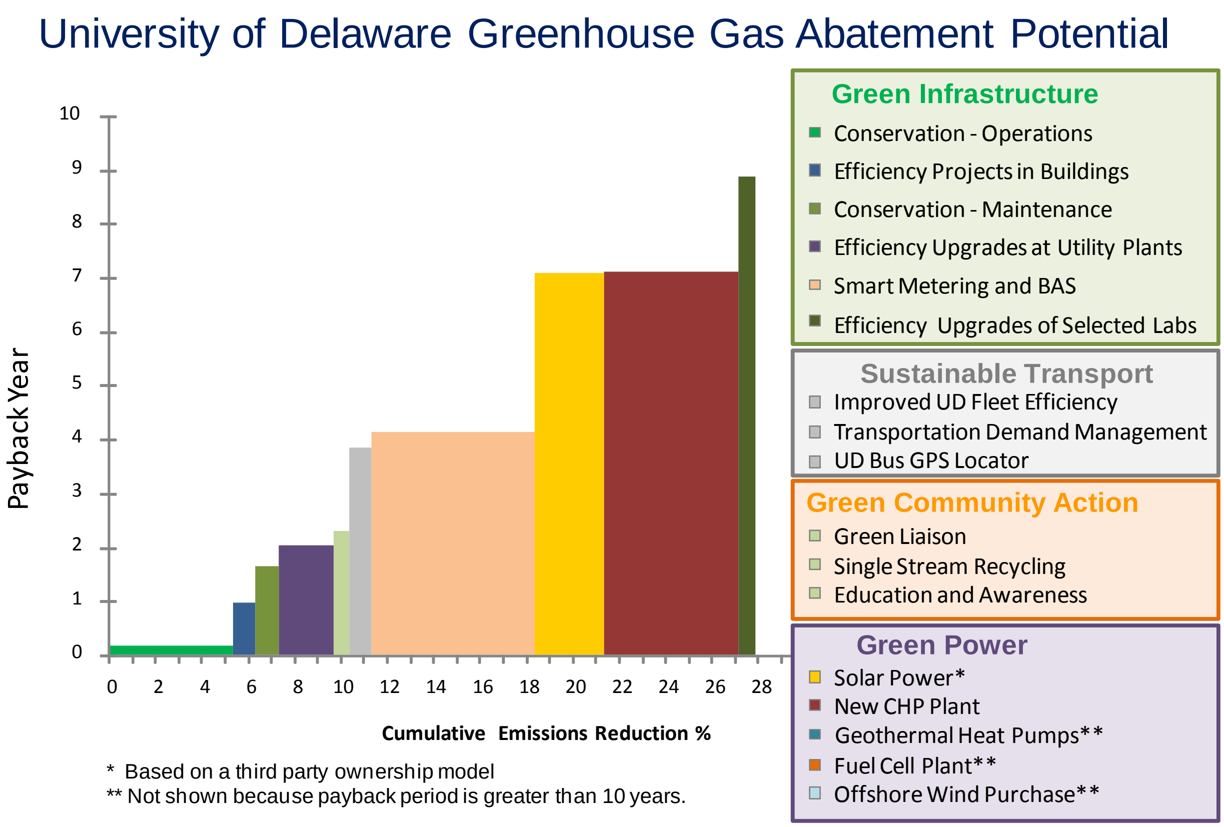
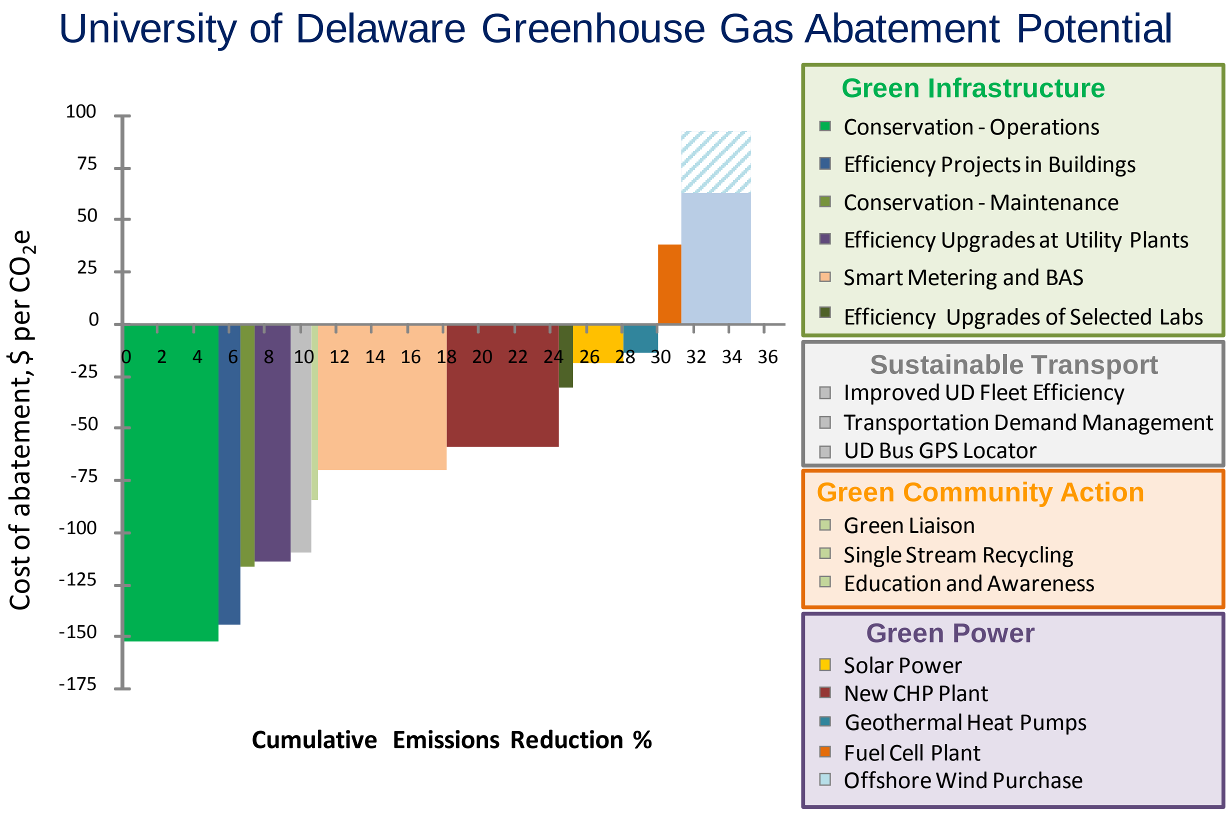


Figure 3: Carbon Abatement Cost Curve



As the University strives to become an innovative leader and establish its reputation as a green and sustainable campus, initiatives which offer opportunities to showcase technologies in which our research programs are expert and those which engage and challenge the campus community need to be implemented.

Summary of the 10-year Plan and Targets

3-Year Target

Items selected for the Plan's 3-Year target are intended to accomplish five purposes:

- Ensure University leadership among peer institutions addressing the problem of climate change;
- Produce early and substantial energy bill savings for use in financing subsequent phases of the Action Plan;
- Establish an early and substantial commitment to solar electricity use in recognition of the University's national "center of excellence" status for this technology.

- Demonstrate the University's intent to comprehensively pursue a green buildings strategy and a sustainable transport system;
- Reflect the commitment of the Plan to involve all community members in the process.

Detailed descriptions of each action are described in a later section. The items from which the University can choose to meet the 3-Year Target are briefly noted below.

- Conservation Operations;
- Efficiency Projects;
- Conservation Maintenance;
- Efficiency Upgrades at Utility Plants;
- Sustainable Transport;
- Green Community Action;
- Solar Power.

The initial cost, annual savings and average payback are for the 3-Year Target of the Plan is reported below.

Table 1: Option to Meet the 3-Year Target of CO_2 Reduction ≥ 5%

Action	Initial Cost	Annual Savings	Payback Year
Conservation Operations	$150,000	$1,030,000	0.1
Efficiency Projects	$320,000	$340,000	0.9
Conservation Maintenance	$430,000	$265,000	1.6
Efficiency Upgrades at Utility Plants	$1,680,000	$835,000	2.0
Sustainable Transport	$570,000	$140,000	4.1
Green Community Action	$250,000	$110,000	2.3
Solar Power	$0.14/kWh	$98,000	7.1
Total	$3,400,000	$2,818,000	1.2

Note: The Solar Power project assumes third party ownership of the system with the University acquiring the systems' output through a power purchase agreement. Presently, the University pays an average price of $0.12 per kWh and the U.S. Energy Information forecasts an increase in electricity prices of 2.1% per year.

5-Year Target

Items included in the 5-Year Target were chosen to serve additional purposes to those for the 3-Year Target.

- Establish the University's commitment to a comprehensive menu of renewable energy options, including geothermal applications;
- Assure a Green Infrastructure with high building standards and "intelligent" building management;
- Include the University's major laboratories in the transition to a low carbon campus.

Detailed descriptions of each action occur in a later section. Additional items to meet the 5-Year Target are briefly noted below.

- Energy Management System
- Efficiency Upgrades of Selected Labs;
- Geothermal Heat Pumps;

The initial cost, annual net savings and average payback are for new items to meet the 5-Year Target of the Plan.

Table 2 Option to Meet the 5-Year Target of CO_2 Reduction ≥ 10%

Action	Initial Cost	Annual Savings	Payback Year
Energy Management System	$7,000,000	$1,700,000	4.1
Efficiency Upgrades of Selected Labs	$1,500,000	$150,000	10.0
Geothermal Heat Pumps	$0.097/kWh	$245,000	11.3
Total	$8,500,000	$2,095,000	4.1

Note: The Geothermal Heat Pumps Power project assumes third party ownership of the system with the University acquiring the systems' output through a power purchase agreement. Presently, the University pays an average price of $0.12 per kWh and the U.S. Energy Information forecasts an increase in electricity prices of 2.1% per year.

10-Year Target

The 10-Year Plan enables the University to invest in new technologies that "green" its supply of energy. This includes:

- A major investment in offshore wind generation;
- The replacement of its central utility plant with a state-of-the-art combined heat and power plant;
- The installation of a fuel cell plant, showing the University's commitment to advanced clean energy technology.

These green power projects require significant capital investment and, in the case of offshore wind, a willingness to pay a green premium in order to help the State and the country pursue this important option. Savings accumulated in the early years of the Plan are employed to support our University's commitment to be a leader in green power.

The initial costs, annual savings and average payback are for new items to meet the 10-Year Target reported on the following page.

Table 3 Option to Meet the 10-Year Target of CO_2 Reduction ≥ 20%

Action	Initial Cost	Annual Savings	Payback Year
CHP Plant	$13,050,000	$1,770,000	7.1
Fuel Cell Plant	$2,150,000	$70,000	30.7
Offshore Wind Purchase	$0.18/kWh	-$640,000	-
Total	$15,200,000	$1,200,000	12.7

Note: Wind cost is a projected 2015 retail price based on communications with the Electric Utility Department of the City of Newark. It includes a 2.5% annual price escalation.

Summary of All Planning Phases

Table 4 summarizes the carbon impact, cost and paybacks of all these phases.

Table 4: Initial Estimates of Action Plan Impacts & Costs

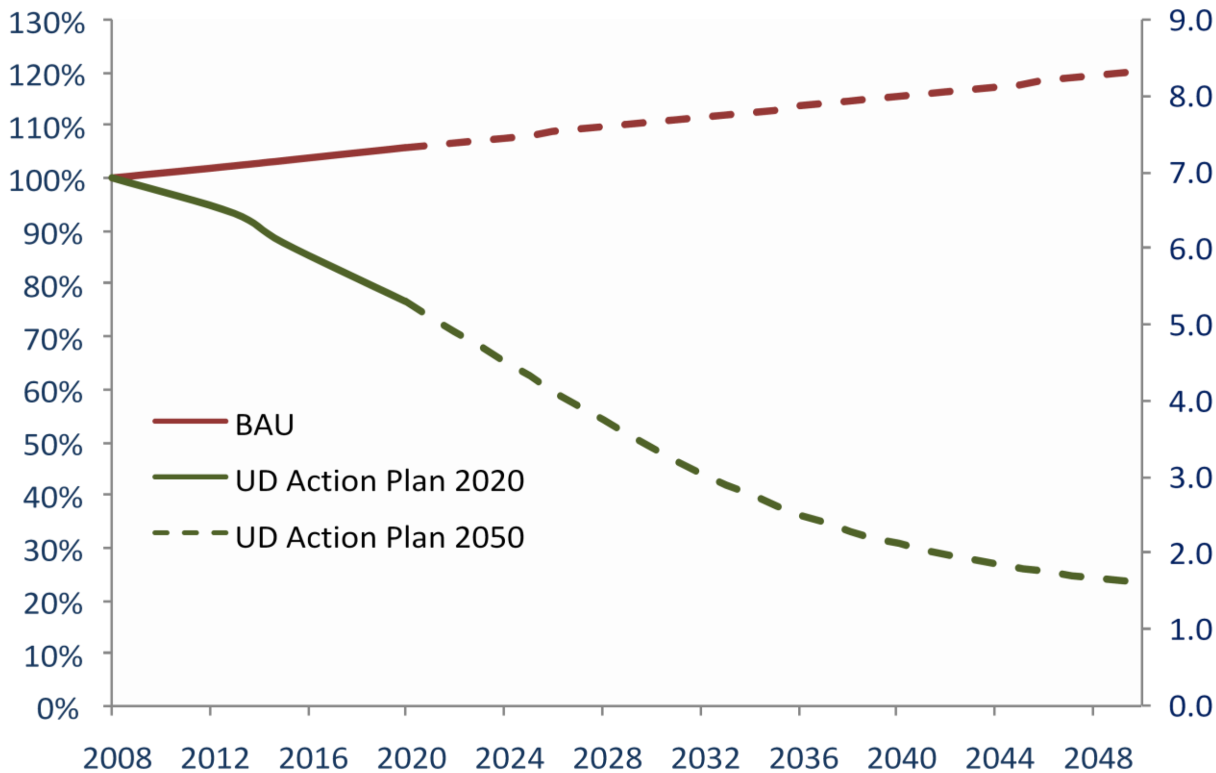
Time Frame	Cumulative Carbon Savings (compared to BAU)	Cumulative Carbon Savings (compared to 2008)	Aggregate Initial Costs*	Aggregate Annual Savings	Payback Year
3-Year Target (2010-2013)	14.0%	10.4%	$3,400,000	$2,818,000	1.2
5-Year Target (2010-2013)	22.4%	17.7%	$11,900,000	$4,913,000	2.4
10 Year Target (2015-2020)	35.3%	28.4%	$27,100,000	$6,753,000 - $640,000	4.0 ** 4.4***

* Does not include capital costs for solar, geothermal and offshore wind projects because these initiatives are expected to be developed through third party ownership structure.
** Without fuel cell plant and offshore wind purchase.
*** With fuel cell plant and offshore wind purchase.

Action Plan Impact on Carbon Emissions

By implementing the Action Plan, the University of Delaware will lower its total carbon emissions by 20% in 2020. After 2020, the University will need to plan for continued cuts in emissions in order to contribute fully to a proposed national commitment, announced by President Obama[6] on April 22, 2009 of a reduction in carbon emissions by 2050 of at least 80% cut from current levels. Importantly, the carbon reduction to meet this commitment are the same or slower than those in the Action Plan (see Figure 4).

Figure 4: Long-term Impact on Carbon Emissions per Student



University of Delaware Climate Action Plan

This section provides an overview of the projects modeled for the University's GHG Action Plan. For estimations on CO_2 reductions, payback and cost per ton of CO_2 abated, please refer to Appendix 2. The costs and carbon savings associated with the projects laid out in this report are estimates and are subject to change. Please refer to Appendix 4 for a description of calculations and assumptions.

[6] http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-in-Newton-IA/

Green Infrastructure

One of our University's most valuable assets is its building stock. Our buildings are where we teach and conduct research; where we are inspired by the artistic expressions of our members; where we share and debate ideas in public forums; where we socialize and share meals with each other; and where many of our students reside. A key to a green and sustainable campus is a built environment which reflects our values.

Investing in green infrastructure reduces the energy, water and materials consumed by buildings. Several projects in the Action Plan utilize behavioral and technological tools that increase energy building efficiency and promote conservation. The following proposed projects, which can be classified under the areas of conservation in operations, building efficiency upgrades, conservation through maintenance, and building automation fall within this category:

Conservation - Operations

G1: *De-lamping*

In the sample of buildings audited, lighting accounts for 10 - 64% of total building electricity use. One simple and costless way to reduce electricity consumption is to remove bulbs within fixtures in over-lit interior areas. A lighting survey of major campus buildings should be completed to identify lighting reduction opportunities.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$0	3,002

G2: *Establishment of an Energy Management Function*

The University does not currently have an explicit energy management function. Creating such a function in Facilities would allow the University to analyze current energy indicators and centrally coordinate and track energy efforts on campus. Responsibilities of an energy management function would include tasks such as energy billing and metering analysis, performance analysis, project management, utility plant upgrade analyses, building information systems maintenance and budget development.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
n/a	1,218

G3: *Operational Measures at the Central Utility Plant (CUP)*

The University operates a Central Utility Plant which provides heat, chilled water and cooled air to 92 buildings comprising 68% of the Newark Campus total square footage. These buildings are commonly served by a steam loop. These measures include isolating CUP steam district loop in summer –as space heating is not required in summer, reducing CUP steam pressure in summer – this saves significant amounts of energy at CUP, and resetting CUP chiller send-out in winter – as space cooling is not required.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$0	431

G4: *Change of Temperature Set Points for Campus Buildings (3 degrees in winter, 2 degrees in summer)*

The cooling and heating loads in campus buildings can be reduced considerably without losing comfort levels by decreasing building thermostat set points. The Action Plan recommends a three degree Fahrenheit reduction in winter and an increase in building thermostat set points by two degrees Fahrenheit in summer. This reduction in cooling and heating loads will result in corresponding reduction in campus energy consumption and CO2 emissions.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$ 50,000	3,612

Building Efficiency Upgrades

G5: *Increasing Lighting Efficiency*

Projects in this category reduce lighting energy use in buildings by substituting more efficient technology. Examples of efficient lighting projects include replacing incandescent with CFLs and installing occupancy sensors so that lights automatically turnoff when not in use.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$273,000	1,553

G6: *VendingMiser*

Each vending machine uses more than 3,000 kWh of electricity each year.[7] In most cases, these machines are on constantly to cool their contents and to illuminate displays. VendingMisers can be installed in most standard vending machines and save an average of 46% of the energy they consume.[8]

Initial Cost	Annual CO_2 Savings (Metric Tons)
$45,800	94

G7: *Install Low-Flow Shower Heads in Dorms*

This is an easy and economical project for our campus. Low flow shower heads (2.5 gallons per minute or less) can reduce bathing water consumption by over 50% and hence corresponding energy requirements to heat the water are also reduced. There are many advantages to this project: reduced energy consumption, reduced energy bills, water conservation and lower water and sewer bills.[9]

Initial Cost	Annual CO_2 Savings (Metric Tons)
$32,166	250

Conservation-based Maintenance

G8: *Renew Drake Lab "Unoccupied" Mode*

By implementing this action, electronic devices which control the building HVAC systems will operate only during the hours scheduled as occupied and will shut off the system during scheduled unoccupied hours. Drake Lab currently has significant energy consumption during unoccupied hours. Re-commissioning building controls can reduce energy consumed during unoccupied periods. Overrides to unoccupied mode can be provided if the Lab needs to be used during hours originally scheduled as unoccupied hours.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$75,000	360

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[7] "Save up to $150 each year with an ENERGY STAR Vending Machine" Available at: http://www.energystar.gov/ia/products/vending_machines/Fact_Sheet.pdf

[8] http://www.vendingmiserstore.com/

[9] For details on the synergistic benefits of energy and water conservation, see CEEP's 2008 report *Integrated Policy and Planning for Water and Energy,* Available at: http://ceep.udel.edu/publications/2008_ws_SET_water-energy_nexus.pdf

G9: *Rebuild Mckinley Heat Wheel*

Heat wheels are air-to-air heat exchangers coated with desiccant material. In the winter, heat wheels transfer heat and moisture from the building exhaust air to the cold and dry incoming air. In summer, the process reverses with humidity and heat transferred from incoming air to the building exhaust air. Efficiently operating heat wheels can significantly reduce the cooling and heating loads on CUP. Rebuilding the heat wheel at Mckinley laboratory will reduce the heating and cooling loads on the CUP, hence reducing energy consumption and CO_2 emissions.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$100,000	312

G10: *Insulate Steam Lines in Vaults*

Insulating portions of the steam distribution system that are currently not insulated will result in considerable reduction of heat loss from the pipe work, a decrease in steam demand and a net reduction in the amount of natural gas necessary to produce steam.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$195,000	250

G11: *Steam Trap Leak Detection and Maintenance*

Steam traps are used to retain steam in the steam lines and to release non-condensable gases and condensate. Thus, steam traps allow condensate and non-condensable gases to escape while holding steam in the device where heat transfer occurs. Leaking steam traps refer to a malfunction where traps fall open and plumes of steam escape from the condensate return system. This leads to energy waste as steam blows through the trap and associated heat cannot be extracted in the exchanger. Steam trap leak detection and maintenance can prevent these energy losses.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$25,000	238

Efficiency Upgrades at Utility Plants

G12: *Auto Blowdown at CUP and Worillow boilers and Heat Recovery at CUP*

High concentrations of dissolved solids in boiler water can lead to foaming and carryover from boiler water into the steam. This could lead to water hammer damaging the piping, steam traps or process equipment. Boiler water should be discharged (blown down) periodically to reduce levels of suspended and dissolved solids. Existing manual blowdown is not optimal as there is no way to determine the concentration of dissolved solids. An automatic blowdown-control system optimizes surface-blowdown rates based on the concentration of dissolved solids present. Auto blow down systems are proposed at CUP and Worillow boilers.

Further, water blown down from boilers is at high temperature and pressure and safety and environmental regulations require water to be depressurized and cooled to prevent over-heating of drains. This is accomplished by using blowdown tanks. But in the process, thermal energy present in the water can be lost. By installing a blowdown heat recovery unit to the CUP boiler, most of the thermal energy in blow down water can be recovered and used to heat boiler feed water. This not only reduces overall energy consumption by the boiler but also reduces the cost associated with cooling the blowdown water before draining it.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$125,000	459

G13: *CUP Turbine Expansion [Distributed Power using a Backpressure Turbine]*

Through backpressure turbines, exhaust steam pressure is controlled by a regulating valve to suit the pressure needs of a steam distribution system. This reduces energy losses associated with steam pressure correction by throttling to achieve proper pressure levels for steam distribution.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$678,000	1,324

G14: *CUP Condensate Heat Recovery*

Steam that is condensed back in to water by either raising its pressure or lowering its temperature is called condensate. Condensate comes from steam traps, heat exchangers, condensers etc. The temperature of condensate (water) is still significantly high and can be recovered to heat the boiler feed water. This improves the overall boiler efficiency.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$7,500	13

G15: *Oxygen Trim at CUP and Pencader Boilers*

Boilers mix air with fuel to provide oxygen in the combustion process. For safety reasons, "*excess air*" is always provided to assure that all fuel is burned safely inside the boiler. Stack heat losses can be decreased and combustion efficiency can be increased by operating the boiler with a minimum amount of excess air. Oxygen trim control provides more precise fuel-to-air ratio control and hence higher boiler efficiency, while reducing stack loss and fuel consumption. Typically, boiler efficiency increases by about 1% for each 15% reduction in excess air. Oxygen trim control systems are proposed for boilers at Pencader and CUP.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$273,000	435

G16: *Install Economizers on Central Utility Plant Boilers*

Economizers (or heat recovery systems) in boilers recover heat from the flue gases and preheat the boiler feed water. Economizers not only reduce the stack losses but also improve boiler efficiency and reduce natural gas consumption.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$85,000	155

G17: *Free Cooling at the CUP*

It is possible to use outdoor air to provide what is generally referred to as "free cooling," that is, meeting a cooling requirement by using cooling tower and outdoor air without having to use a mechanical chiller. "Free cooling" can be used as long as the ambient temperature is sufficiently low (typically about 61° F or lower).

Initial Cost	Annual CO_2 Savings (Metric Tons)
$36,428	357

G18: ***CUP Boiler blow down reduction using reverse osmosis Make-up system***

Boiler feed water needs to be discharged (blown down) periodically to reduce levels of suspended and dissolved solids. Typically 5 to 6% of feed water (at about 240 degrees and 125 psig pressure) is lost from the boilers due to blowdown. Make up water used to replace this discharge is normal city supply water (at 60 degrees). This needs to be heated in the boiler to about 240 degrees. This heating load on the boiler can be reduced by using purified water from a reverse osmosis system in place of city supply water.

It is estimated that an RO system for boiler make up water would reduce the blow down losses by 80% at the CUP.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$200,000	364

G19: ***Add Steam Turbine-Driven Feedwater Pump at CUP***

The preferred boiler feedwater pump today is the turbine-driven pump because it increases the net output of a power plant by eliminating the electric power consumption required by electric boiler water feed pumps. Furthermore, the steam turbine's variable speed equipment eliminates the need of a variable speed device (which would be required with an electric motor).

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$75,000	83

G20: ***Secondary Pumping Optimization***

The objective of pumping optimization is to provide sufficient water supply to the CUP by avoiding excess differential pressures across valves. This is generally achieved by equipping the pumps with variable speed drives (VSD).

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
NA (Quotes will be obtained)	76

G21: ***Metering and Building Automation System***

Utilizing tools that enable automated control, measurement, and analysis of building energy and fuel consumption processes can improve oversight and reduce energy used in buildings. Data from building-level metering can be used to observe trends, improve cost allocation accuracy, and serve as a basis for justification of technological and behavioral conservation.

Technology such as direct digital control and building automation systems enable facility managers to match energy consumption to demand. Building level energy metering, tracking, and analysis systems, which also fall under this category, offer building managers the ability to measure usage and detect irregularities in usage patterns, which can lead to the identification of additional opportunities for efficiency, maintenance and operational upgrades.

This project is one of the largest to be recommended, and could take as long as 5 years to complete. For this reason, it is recommended that buildings be prioritized, based on characteristics such as estimated energy use, size, and function.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$7,000,000	10,911

G22: *Outside Air Reheat Recovery for 4 Labs*

Four labs are proposed for this project namely Wolf, Brown, New Dupont and Colburn Lab. All these labs draw outside air and the ventilation rates (viz. air changes per hour) are very high. Venting conditioned air at high rates means greater need for heating / cooling of the outside air drawn in to the building. This also means more energy consumption.

However heat can be recovered from the air being vented out by using air to air heat recovery systems (like the enthalpy wheel) or air-liquid heat recovery systems (like the glycol loop).

Enthalpy wheels are large spinning wheels with desiccant layer on their surface placed in the path of incoming and exhaust air streams. They exchange heat and humidity between exhaust air-stream and incoming air stream.

The glycol loop heat recovery system uses a coil with glycol acting as a heat exchange fluid (similar to a refrigeration cycle) and helps to recover sensible heat from exhaust air stream without mixing it with the incoming air stream.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$1,146,518	993

Green Power

Green power uses renewable sources of energy such as the sun and more efficient processes to produce electricity and heat. The research team considered the following green power projects:

P1: *Photovoltaic ("PV") Power*

Photovoltaic power utilizes energy from sunlight to create electricity. Since electric generation using this technology is fueled directly by solar energy, no greenhouse gases are emitted. Replacing conventional electricity with solar power has the potential to significantly reduce the University's GHG emissions. An additional benefit of PV power is its low maintenance and operations costs.

As noted earlier in this report, the University of Delaware earned "Center of Excellence" designation from the U.S. Department of Energy for its decade-long leadership in photovoltaics research. PV sales are growing at a faster annual rate than any other energy option. The technology supporting rapid growth can in many instances be traced to innovations created at our University's Institute of Energy Conversation.

In recognition of this record of excellence, the research team was asked to explore options for use of this technology on our campus. A detailed survey of building roofs and garages was conducted to determine suitable host sites. Financial analyses were also performed using a power purchase agreement (PPA) model involving third-party ownership for at least a part of the technology's useful life.[10] An investment expert was asked to review the team's analyses and submitted additional analyses for University review.[11]

Based on what it has learned, the research team has recommended a 3-year plan to install 6 MW of solar power at the Newark campus in 2 MW annual increments. When completed, this project will establish the University as host to the largest campus installation of PV power in the world.

The financial basis for this decision is simple: the University will seek, through a competitive bidding process, to purchase power from the solar plant hosted on its campus at an initial green premium of 1.0 to 1.5 cents per kWh. Based on a projection of the likely long-term cost of electricity from non-renewable sources, it is expected that University payments for solar electricity will be less than it would cost to purchase grid power in 5 – 8 years. Because the University will not initially own the solar plant, it will incur no capital cost.

[10] Third-party ownership is necessary to capture tax benefits available under federal law only to private owners.
[11] The expert is an alumnus of the University and provided review and analyses at no charge.

The CO_2 benefits from the project will be large (approximately 6% lower emissions from campus electricity use) and long-lasting (PV equipment has a projected useful life of 25-30 years).

Cost	Annual CO_2 Savings (Metric Tons)
0.14/kWh	4,524

Note: This is a modeled 2010 PPA price based on a telephone survey of developers.

P2: *Combined Heat and Power ("CHP")*

Combined heat and power plants integrate the generation of useful heat and electricity. The process recovers heat that is usually wasted and uses it to meet heating demand for water heating and cooling.[12] Due to the time, cost and complexity of building a CHP plant, it is recommended that a project is carried out in 10 of the Action Plan. The research team looked into the cost and carbon savings associated with building a 4 MW CHP plant that would provide onsite campus electricity and base load heating supply.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$2,184,000	9,690

P3: *Geothermal Heat Pump*

Geothermal heat pumps (GHP) use the constant temperature of the earth as the exchange medium for HVAC instead of the outside air temperature. A few feet below the earth's surface, the ground remains at a relatively constant temperature - 55 degrees Fahrenheit. GHP technology takes advantage of this temperature difference by exchanging heat with the earth through a ground heat exchanger.

It is estimated that a reduction potential of nearly 3,000 metric tons of CO_2 emissions annually can be achieved if approximately 900,000 square feet of building stock is served by this technology. Currently, two-thirds of the building stock on the Newark campus (or 3.9 million square feet) is served by the Central Utility Plant and other University power plants. GHP service could be considered for about one-half of the remaining building stock served by building-sited equipment. Potential buildings not connected to the CUP or other Utility power plants should be identified based on their energy use profiles (higher occupancy, significant cooling/heating loads, base load demand, etc.), GHP installations should be scheduled in connection with significant energy efficiency upgrades, and when replacement of the HVAC system is planned.

[12] American Council for an Energy-Efficient Economy. "Combined Heat and Power and Distributed Generation." Available at: http://www.aceee.org/chp/

Cost	Annual CO_2 Savings (Metric Tons)
$0.12/kWh	2,994

Note: Assumes a PPA with a third party investor at $0.12/kWh.

P4: *Fuel Cell Plant*

Fuel cells chemically combine hydrogen (present in a suitable fuel) with oxygen to produce electricity creating heat and water as byproducts instead of harmful carbon emissions. Fuel cells are highly efficient and less polluting compared to conventional fossil fuel combustion based generation systems. Including a fuel cell power plant from the design phase of a new building can significantly lower costs.

A fuel cell based CHP system would reflect our University's commitment to invest in advanced technology for a sustainable future. Such a measure will promote the objectives of the Center for Fuel Cell Research (CFCR) at the University.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$15,258,134	1,604

P5: *Offshore Wind Purchase by the City of Newark*

The University will participate in the purchase of offshore wind power as part of the decision by the City of Newark to acquire 12,897,196 kWh annually. The University share would be approximately 1.3 million kWh in 2015 and could lead to yearly carbon reductions of more than 6,000 tons at an initial price of approximately 18 cents per kWh. The offshore wind purchase price will escalate at 2.5% per year.

Initial Cost	Annual CO_2 Savings (Metric Tons)
$0.18/kWh	6239

Note: This is a projected 2015 retail price based on communications with the Electric Utility Department of the City of Newark. It includes a 2.5% annual price escalation.

Sustainable Transport

University transportation activities are the second largest source of carbon emissions at 21.8% (33,334 $MTCO_2$), which is largely due to the significant amount of student and faculty commuters. In fact of the 33,334 $MTCO_2$ generated by transportation activities, emissions from the university fleet (bus, facilities repair vehicles, public safety, etc) only account for approximately 8% of the total transportation releases.

In order to significantly reduce transportation emissions, the University community must change transportation habits. Unfortunately, the University does not enjoy the transportation advantages that other institutions possess (such as pedestrian-friendly urban environments or locations with robust light rail networks). However, by working with local and state agencies, the University can seek greater transit opportunities while implementing more transportation demand management strategies at the campus in order to significantly reduce emissions. While the university fleet remains largely dependent on diesel and gasoline at the moment, the University's fuel cell bus, which has been operating across the campus since April 2007, offers a special opportunity to enlist faculty and researchers in the College of Engineering.

Because commuter vehicles are neither owned nor controlled by the University, emission reductions can only occur through programs that aim to alter the behavior or mode of transportation of the campus's commuting population. The research team examined programs and proposals from the community. One such program would award $200 bike vouchers to students and faculty who agree not to purchase a parking permit for a given amount of time. Another uses GPS technology to allow campus community members to track the location of University shuttle buses. These and other strategies are addressed below.

S1: *Comprehensive Transportation Plan*

The University's Campus Assessment and Capacity Study calls for our community, "to evolve from an automobile-oriented campus to a more balanced, well-connected campus."[13] In order to significantly reduce transportation emissions, the University must develop a comprehensive set of policies. Although this plan calls for the implementation of several short-term changes, a long-term solution is needed. Many universities across the country have turned to developing transportation plans to identify parking needs and strategies, short-term issues such as additional bike racks, as well as long term capital investments including additional bus purchases, improved bikeways and pedestrian access points. This will require a thoughtful plan and partnerships with the City of Newark and State of Delaware.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$670,000	1,620

S2: *Increase carpooling across campus*

In previous years, between 10 and 20 carpools operated on campus. In order to reduce carbon emissions from vehicles, the University should increase incentives and publicity for this option.

[13] www.udel.edu/capacity

A number of policy changes will make it more attractive. First, all university carpoolers can be made eligible for the state's guaranteed ride home service, provided by registering their carpool with the Delaware Transportation Management Association. The University will assist registration. Second, the University should increase the number of free daily gold passes given to each member of the carpool from 10 to 40 per year. This will allow individuals the flexibility to drive separately when work or personal schedules prohibit carpooling. Third, the University's ride-board website should be utilized to a much greater extent. This site enables employees and students to post their commutes and identify fellow commuters. Last, individuals who carpool will receive assignment preference for gated lots.

Additional options assessed by the research team include financial incentives for carpooling and registering student car permits. Further work on these options is needed.

S3: *Require purchase of high efficiency vehicles in the University fleet*

Where vehicle function is not significantly compromised by purchasing a more efficient model, it should be fleet procurement policy to purchase the most efficient vehicle possible. Where feasible, hybrid vehicles should be used to replace current fleet vehicles. Other ways to reduce fleet related emissions include purchasing the most efficient vehicle in the desired fuel class, and downsizing vehicle class when possible.

It is expected that the University will substantially improve the combined vehicle fuel efficiency of its fleet within the next five years.

S4: *Improve and expand the University shuttle service*

According to the 2008 Spring Transportation survey, staff and faculty called for increased frequency and reliability to utilize the bus service more frequently. Given the present schedule of service, 91% of faculty and staff survey respondents indicated they never use the shuttle system to move around campus. Conversely, the majority walked, carpooled, or drove alone[14].

Increasing bus quality, the frequency of service and on-time performance were examined as a means to attract more faculty, staff and student bus riders to and from meetings and classes and diminish the use of private vehicles for on-campus transport.

[14] 60% reported walking a majority of the time and 20% reported frequently driving alone.

The recent purchase of new transit-style buses reflects the University's commitment to develop a higher quality and frequency of service. In order to encourage more staff, faculty, and student use of the bus service, it is recommended that the University develop or purchase GPS locators for the University buses. This would enable students, staff and faculty to see real-time locations of the entire bus fleet.

S5: *Create an Alternative Transportation Fund*

In order to provide the community with greater alternative transportation options such as transit, carpooling, and bicycling, the University will have to expand existing facilities and provide more robust incentives. The University's first-ever transportation survey highlighted the need to upgrade campus bike lanes, replace and add bike racks at high-demand locations and provide different incentives for traveling to and from as well as around campus.

Therefore, it is recommended that the University institute a "fee bate" structure to fund several transportation demand management programs that both encourage alternative transportation and discourage single occupancy trips.

This Climate Action Plan has set the goal of reducing the number of cars traveling to campus by 400 by 2013 through a combination of carpooling, bicycling, walking and improved bus service. This will require additional resources. Therefore, it is proposed that a percentage of each University parking permit sale is devoted to an Alternative Transportation Fund. This would fund several transportation demand management programs that encourage alternative transportation and discourage single occupancy trips.

Sustainable Community Action

To achieve a low-carbon campus, we must change not only our technology but our behavior, practices and policies. Several policy changes have been identified above. In this section, we focus on community actions that can facilitate the changes we need to embrace in our behaviors and practices. The items highlighted here are only the beginning. Much more can and should be done. Changes by the campus community are key to significantly role in reducing the University's emissions. Although estimations of reductions resulting from community modifications can be difficult to quantify, they can contribute substantially to achieving emissions reductions, by increasing awareness, demonstrating how practical actions make a difference, and enlisting everyone to identify and address the challenges of sustainability.

The University must use its educational and research excellence to instill an ethic of environmental responsibility. Initiatives should include campaigns, seminars and competitions to influence the behavior of students, faculty and staff to make decisions that minimize energy, water and materials waste and encourage recycling. One example of such an initiative is a dorm electricity use competition which would reward the dorm that manages to reduce its electricity use the most. Bowdoin College conducted a dorm energy competition in 2004 and as a result reduced dorm electricity use by 24.7%.[15] Initiatives like these can have significant results at very little cost, while also serving as a learning experience for the students and for the entire community.

C1: *Green Liaison Program*

The goal of the Green Liaison Program is to ensure that the entire campus community remains involved in the University's GHG reduction initiative. The program would accomplish this objective by soliciting volunteers from every dorm and every academic and administrative department to function as a clearinghouse and a coordinator of projects relevant to the University's Action Plan. This person's primary duties would be to reduce energy usage and encourage recycling within their assigned department or dorm. In addition to distributing information, this person would also filter ideas and concerns from campus members to add new ideas and improve existing policies.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$37,500	412

C2: *Single Stream Recycling*

For the past five years, our University recycled, on average, approximately 16% of its solid waste. This figure will increase due to the University's plan to improve its recycling infrastructure and deploy a single-stream recycling program. Increasing the University's recycling rates are not solely a matter of infrastructure. Community participation will be key to the actual performance of the new program. Results of the single-stream recycling pilot program implemented at part of the University shows an increased recycling rate of 26%.

Initial Cost	**Annual CO_2 Savings (Metric Tons)**
$210,000	259

C3: *The UD Sustainability Task Force*

The Sustainability Task Force is a University-wide organization that includes faculty, staff, graduate and undergraduate students. Its mission is to identify and promote actions by community members that improve the University's contribution to a sustainable future. The Task Force strives to make sustainability a part of the University curriculum and research agenda, and works

[15] Sustainable Bowdoin " Energy Conservation Dorm Competition 2004: "When not in use, turn off the juice"" Available at: http://www.bowdoin.edu/sustainability/campus-involvement/pdf/winter2005.pdf

to integrate sustainability into all aspects of University life and practices. Meeting tweice each month, the Task Force has created the University's annual Sustainability Day and several other awareness-building initiatives.

The involvement of this Task Force in the implementation of University's Climate Action Plan will be highly valuable going forward. It should serve as the University-wide clearinghouse for the critical challenges of promoting a sustainable community.

C4: *Green E-Letter*

In support of the University's environmental efforts, a green e-letter should be produced monthly. Each month, this e-letter would have a central theme regarding green practices individuals could undertake. In addition, the e-letter would be a vehicle for green liaisons to use in promoting various green efforts within their various organizations by including best practices for reducing energy (e.g. using utility strips to eliminate phantom loads) and highlighting university policies which encourage sustainable behavior (e.g. vanpool incentives). It would also recognize individuals, departments or units that completed a project in support of the University's environmental efforts.

Candidate Projects Identified for Further Consideration

The research team has identified several candidate projects for additional analysis. Two of these are highlighted below.

One source of emissions not included in the Inventory are those from wastewater treatment. The treatment of wastewater is an energy intensive process, and reducing the volume of wastewater generated is one way in which the University can diminish its indirect energy usage. This source of emissions was excluded for comparability purposes, as peer institutions and standards consulted did not consider this process. Several projects like this one would certainly have a positive environmental impact.

Emissions resulting from student, faculty, and staff commuting are a significant part of the University's emissions. However, cost savings from emission reductions efforts in this area accrue to the individual only. This complicates efforts to evaluate the feasibility of projects aimed at reducing emissions in this area. Emission reduction projects have been recommended in this area, but it is difficult to compare their costs and benefits with other projects utilizing a common methodology. The research team will continue work on the assessment of projects focused on commuting.

Candidate projects recommended for further quantitative analysis in this area are introduced in Appendix 3.

Challenging the Community

To meet the objectives of the Action Plan, it is essential that we enlist the efforts of all members of the University. Further, we should coordinate with our surrounding community, especially in areas such as sustainable transport where cooperation and coordination with city, county, state and regional initiatives are essential.

As a leader in the development of new ideas and technological innovation, the University understands its obligation to embrace new policies, practices, behaviors and technologies. Our actions should serve as an example to our community of the values we cherish. By implementing the Climate Action Plan, the University hopes to produce programs, policies and technology developments that can help the wider community and society.

Utilizing the University's Solar Expertise

In early 2008, the University of Delaware's Institute of Energy Conversion (IEC) received a grant for $3.75 million from the U.S. DOE to continue its cutting edge solar cell research.[16]

For more than 35 years, the IEC has been the country's leading university laboratory for the design of solar cells and cell manufacturing. In 1992, it earned and has continuously maintained its status as the U.S. Department of Energy "Center of Excellence" in solar electric technology.

Embarking upon a University carbon reduction plan using solar photovoltaic technology as one of our initiatives will go hand in hand with the research occurring at the University. By investing in PV technology, the University supports engineering research that its IEC has pioneered and encourages faculty, research staff and students to redouble efforts to invent the next-generation solar electric technology.

Fuel Cell Technology

In late 2008, the University of Delaware launched its Center for Fuel Cell Research (CFCR). The primary objective of the CFCR is to improve the understanding of and promote the commercialization of fuel cells.[17] This center builds upon the highly regarded research of the University's Center for Catalytic Science and Technology.[18] For 30 years, CCST has pioneered research in energy technology and its collaboration with CFCR can enable our campus to benefit from fuel cell technology in the future.

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[16] UD Daily "UD receives a $3.75 million DOE grant for leading-edge solar research" http://www.udel.edu/PR/UDaily/2008/mar/solar032408.html

[17] UD Daily "University of Delaware launches fuel cell center" Dec. 10, 2008. Retrieved on March 17, 2009 at: http://www.udel.edu/udaily/2009/dec/fuelcell121008.html

[18] See http://www.che/udel/edu/ccst

The Action Plan proposes the development of a fuel cell plant for the campus, which can utilize University research in its design and operation. The plant will meet practical needs for energy while serving as a working laboratory for University researchers.

Wind Energy Options

The University's College of Marine and Earth Studies (CMES) has played a central role in the efforts in Delaware to explore the use of wind energy harvested by offshore turbines. The City of Newark joined other municipalities in agreeing to acquire a portion of its electricity needs from an offshore wind farm. University students and faculty helped to make this agreement possible and our Action Plan reflects the carbon benefits of this pioneering project. CMES faculty and students will continue their survey research on social attitudes toward offshore wind use, regulatory studies on the barriers and opportunities to the use of this option, and resource assessments that can help to understand intermittency and reliability questions.

Climate Action Planning

The University can be proud of its long-standing contributions to energy and climate policy. For over 25 years, the University's Center for Energy and Environmental Policy has contributed locally and globally to the cross-cutting issues of energy and climate. From its first book publication in 1983, for the American Association for the Advancement of Science on *The Solar Energy Transition,* to its participation since the early 1990s in the Intergovernmental Panel on Climate Change, to its preparation of Delaware's Climate Action Plan,[19] and its creation of the Sustainable Energy Utility,[20] University faculty, research staff and students at CEEP have been at the forefront of building pathways to a carbon-neutral future. This expertise has now been marshalled to assist our community in creating a Climate Action Plan that can make all of us proud.

A Profile of Community Action

The measurement of the University's emissions and creation of the action plan would not have been possible without the funding that resulted from the efforts of students, and friends of the University. The 2008 Senior Class Gift has supported our University's first-ever effort to identify, in a systematic manner, actions to reduce our carbon footprint. The 2009 Senior Class Gift will underwrite the installation of solar panels at

[19] Delaware's Climate Action Plan won "best practice" recognition by the U.S. Environmental Protection Agency and the U.S. Department of Transportation's Volpe Center.

[20] See http://www.seu-de.org This model has been adopted by Washington, D.C. and Philadelphia and recently received national recognition at the Middle Class Task Conference convened by Vice President Joseph Biden in February 2009 in Philadelphia (see http://www.americanprogressaction.org/issues/2009/02/podesta_task_force.html

the Newark campus, a key recommendation of the Climate Action Plan. Both gifts are indicators of our community's ability to embrace the challenge of building a carbon-neutral campus.

The efforts each and every day of our Facilities, Transportation, Landscaping, Custodial Services and Procurement units to lower carbon emissions through practices and purchase decisions that emphasize sustainability standards are further evidence of our community's willingness to rise to the challenges which lie ahead.

The indications above of our community's commitment to a sustainable future should give all members confidence in our ability to meet the aggressive goals of the Climate Action Plan. With hard work and the efforts of all members, we can meet the 10-year challenges set forth in this document.

Future Inventory Development and Action Planning

The 2008 Carbon Inventory is only as comprehensive as the data acquired to calculate it. One source of emissions that was not included in this first emissions calculation is University related business travel (i.e., conference and student activity travel not using university fleet vehicles). Accordingly, the Action Plan does not include recommendations for reducing emissions in this area. Before the next inventory, a system should be established that tracks University-related faculty, staff and student travel.

Additional sources of emissions excluded from the scope for the first inventory are emissions from farming activities and emissions from satellite campuses. In order to engage the University in its entirety and maximize the integrity of the emissions reduction initiative, it is recommended that the scope of subsequent inventories and action plans be expanded to encompass these areas.

Next Steps: Community Participation Planning

The creation of an Action Plan is the beginning of the University's GHG reduction initiative. Much work lies ahead to fulfill its goal. Central to the Plan's implementation is the participation of all members of the campus community. Awareness and education in areas that affect the everyday activities contributing to our carbon footprint is important, which is why, in addition to the technological initiatives outlined in this Action Plan, the University will undertake campaigns aimed at increasing student, faculty, and staff awareness and encouraging participation in the University's carbon footprint reduction process.

As our community becomes more involved and carbon reduction activities at the University gain momentum, it is expected that new and creative measures to further cut GHG emissions will be identified by our members. The University will continue to encourage everyone to remain involved by sharing ideas on how to sustain our role as a leading green campus in the country.

Appendices

A.1 Climate Action Plan Leadership

A.2 Project List

A.3 Candidate Projects for Future Consideration

A.4 Key Calculations and Assumptions

Appendix 1: Climate Action Plan Leadership

Research Team

John Byrne (Distinguished Professor of Public Policy, Director of CEEP)
Ralph Nigro (Research Fellow, CEEP, and Co-director, Industrial Assessment Center)
Lado Kurdgelashvili (Research Fellow, CEEP)
Drew Knab (Project Analyst, University Administration)

Student Researchers

Xilin Zhang (Ph.D., CEEP; prior degrees in electrical engineering)
Bahareh Van Boekhold (MEEP, CEEP; prior degree in architecture)
Candis Robinson (MEEP, CEEP; prior degree in economics)
Veerendra B Veerabhadrappa (MEEP, CEEP; prior degree in mechanical engineering)
Cynelsa Broderick (B.E., Civil & Environmental Engineering)
Richard Parsons (B.E., Mechanical Engineering)
Caitlin Reese (B.S., Economics)
Seth Breggar (B.S., Business Administration)
Lauren Asprooth (B.A., Political Science & International Relations)

Advisory Committee

Scott Douglass (Advisory Committee Chair, Executive Vice President)
Robin Morgan (Dean, College of Agriculture and Natural Resources)
Michael Chajes (Dean, College of Engineering)
Robert Specter (Vice President of Finance)
Bob Stozek (Associate Vice President, Facilities)
Michael Breggar (Director, Life Sciences and Health Care, Deloitte)
Teagan Gregory (President, Student Government Association)

Working Group

Kathleen Kerr (Working Group Chair, Director of Residence Life)
Sue Bogan (Director, Dining Services, Dining Services Liaison)
Margot Carroll (Associate Vice President of Administrative Services, Transportation Liaison)
Anne-Marie Crossan (Maintenance Engineer Facilities & MEEP Student)
Ken Grablewski (Director, Facilities Maintenance and Operations, Campus Buildings Liaison)
Dave Graham (Maintenance Engineer Facilities)
Mike Loftus (Assistant Director, Facilities, Recycling and Single Stream Liaison)
Tom Taylor (Landscape Engineer, Landscaping Liaison)

Appendix 2: Project List

Ref. #	Category	Description	Metric Tons Reduced	Cost/$MTCO_2$ Reduced	Payback
G1	Conservation – Operations	Reduction of lighting to a recommended level appropriate for different usage (de-lamping). Assumes 20% savings in lighting are expected	3,002	($181)	No Cost
G2	Conservation – Operations	Establish an Energy Management function. Responsibilities would include Billing and Metering Analysis, Performance Testing, Project Management, Budget Development.	1,218	($140)	0.7
G3	Conservation – Operations	Operational measures at CUP (Isolate CUP Steam District Loop in summer, Reset CUP Chiller Send-out in winter, and Lower CUP Steam Pressure in summer)	431	($146)	No Cost
G4	Conservation – Operations	Adjusting temperature set points by 3°F in summer and 2°F in winter.	3,612	($133)	0.1
G5	Efficiency - Project	Efficient lighting (replacing incandescent lights with CFLs, installing occupancy sensors)	1,553	($146)	0.9
G6	Efficiency - Project	Equipping vending machines with energy saving equipment (e.g., 'VendingMisers')	94	($117)	2.3
G7	Conservation – Maintenance	Outfit Dorms w/ Low flow Shower Heads	250	($153)	0.6
G8	Conservation – Maintenance	Renew Drake Lab Unoccupied Mode (re-commission building controls to reduce energy consumption during unoccupied periods)	360	($145)	1.0
G9	Conservation – Maintenance	Rebuild Mckinley Heat Wheel	312	($130)	1.5
G10	Conservation – Maintenance	Insulate Steam Lines in Vaults (sections of underground steam lines in areas accessible by manhole)	250	($87)	3.7
G11	Conservation – Maintenance	Steam Trap Leak Detection and Maintenance	238	($51)	1.6
G12	Efficiency Upgrades at Utility Plants	CUP and Worrilow Blowdown Heat Recovery (minimizes energy losses due to water chemistry corrections on boilers)	459	($133)	1.3
G13	Efficiency Upgrades at Utility Plants	Back Pressure Turbine At CUP (reduces energy losses due to throttling steam to correct pressure levels for distribution)	1,324	($133)	2.2
G14	Efficiency Upgrades at Utility Plants	CUP Condensate Heat Recovery (recovers heat from returning steam condensate)	13	($114)	2.7
G15	Efficiency Upgrades at Utility Plants	Oxygen Trim at CUP and Pencader (Laird) Utility Plant (automatically adjusts fuel-air ratio to minimize fuel consumption)	435	($99)	3.3
G16	Efficiency Upgrades at Utility Plants	Installing economizers at CUP boilers (recover waste heat from boiler exhausts)	155	($105)	2.6
G17	Efficiency Upgrades at Utility Plants	Free Cooling at CUP (minimizes electric chiller operation during cool weather by using existing cooling tower)	357	($99)	3.3
G18	Efficiency Upgrades at Utility Plants	CUP boiler blow down reduction using RO Make-up System	364	($98)	3.0

Appendix 2: Project List (Cont'd)

Ref. #	Category	Description	Metric Tons Reduced	Cost/MTCO2 Reduced	Payback
G19	Efficiency Upgrades at Utility Plants	Add Steam Turbine-Driven Feedwater Pump At CUP	83	($60)	5.7
G20	Efficiency Upgrades at Utility Plants	Secondary Pumping Optimization	76	NA	NA
G21	Energy Management System	Install building-level metering for all utilities (i.e., electricity, natural gas, steam, chilled water). Replace controls in buildings that have not yet been upgraded to DDC (direct digital control) for the Building Automation System (BAS). Purchase of energy-tracking/analysis software package	10,911	($71)	4.0
G22	Efficiency Upgrades of Selected Labs	Heat Recovery for Colburn, Brown (North), New Dupont and Wolf Labs	993	($31)	8.9
P1	Green Power	Install 6 MW of PV systems. Project development via third party ownership model to maximize tax benefits (30% Federal investment tax credit, Modified Accelerated Cost Recovery System).	4,524	($19)	7.1
P2	Green Power	Add a 4 MW Co-generation plant to existing Central Utility Plant, (CUP)	9,690	($80)	7.0
P3	Green Power	Geothermal heat pumps (GHP) use the constant temperature of the earth as the exchange medium for HVAC instead of the outside air temperature. A few feet below the earth's surface, the ground remains at a relatively constant temperature - 55°F. GHP technology is recommended to provide space conditioning for 900,000 sq. ft. of building stock served by the CUP or other UD power plants.	2,994	($14)	11.5
P4	Green Power	300 KW Fuel Cell plant	1,604	$39	NA
P5	Green Power	Offshore wind purchase by City of Newark	6,239	$60-92	NA
S1	Sustainable Transport	Replace UD fleet with more efficient vehicles; Increase number car pooling.	1,620	($110)	3.8
C1	Community Action	Establish green liaison for promoting energy conservation and single-stream recycling; also green liaisons will assist in campus education and feedback campaigns.	671	($83)	2.3

Appendix 3: Candidate Projects for Future Consideration

For the following projects, the research team did not have enough information to estimate cost, energy savings, and/or carbon reductions. The team plans to continue efforts to address these options.

Category	Description
Apply for Sewer Credits	Sewer credits are a way to manage new sewer connections by the concerned sewer district. In this system any increase in flows to the sewer would require the user to apply for sewer credits. Sewer credits are generated by sewer improvement projects so that a specified amount of water flow to the sewer is reduced.
Bicycle Voucher Program	Under this program, students and faculty would have the option of forgoing the purchase of a parking permit in exchange for a bicycle voucher, that could go toward the purchase of a bicycle.
Revise Space Management Procedures	Coordinating space management with energy management can result in optimal utilization of energy. Practices that, for example, align class and meeting schedules with energy reduction goals allow for the best possible usage of energy and hence reduced consumption.
Revise FP&C Design Standards to Reflect Energy Savings as a Priority	Facilities Planning and Construction Design Standards should give priority to energy savings. This would not only show the University's commitment to energy efficiency and energy conservation but will also help in moving towards inherent energy efficiency in all systems in the long run.

Appendix 4: Key Calculations and Assumptions

Calculations

Cost per metric ton of carbon[21]

- Using the *Insulate Steamlines in Vaults* plant as an example:
  Calculation of the Net Present Value
  - Initial Cost (IC) = $195,000
  - Cost of gas = $11.5/MCF
  - Additional annual operating cost = $0
  - Project lifetime = 10 years
  - Net Savings (NS) = ($51,000)
  - Fuel annual escalation rate = 2.4% (for natural gas)
  - Discount Rate = 6%

  Calculation of the Lifetime Reductions
  - MCF of gas saved = 4430
  - Annual MTCe reduction = 250
  - Lifetime eCO_2 reductions = 2500

- Cost/Reduction Ratio = $\frac{IC+\sum_{i=1}^{n} NS*(\frac{1+e}{1+r})^{n-1}}{Annual\ MTCDe\ Reduction*n}$ = ($87)

What does this ratio mean? For each metric ton of CO_2 reduced, the University will actually *save* $87 in energy costs via this project.

Assumptions

The following noteworthy assumptions were made in order to calculate indicators for each proposed GHG reduction project:

Fuel assumptions:	Natural Gas	Electricity	Gasoline
Annual Escalation Rates[22]	2.4%	2.1%	3.1%
Initial Prices	$11.5/MCF	$0.12/kWh	$2.00/gal
Discount Rate	6%		

[21] Hummel, Sam, "Charting a path to greenhouse gas reductions." Duke University

[22] Energy Information Administration Annual Outlook 2009 Table A3. *Energy Prices by Sector and Source*

Conversion Factors

Emission factors applied to all sources of University emissions are listed below:

Source	Sector	Emission Factor
Natural Gas	Buildings	.0546 $MTCO_2$/MCF
Distillate Fuel #2 (Heating Oil)		.01015 $MTCO_2$/Gal
Electricity		.00058 $MTCO_2$/kWh
Gasoline	Transportation	.0088 $MTCO_2$/Gal
Diesel Fuel		.01015 $MTCO_2$/Gal
Jet Fuel		0.0096 $MTCO_2$/Gal
Mixed Solid Waste	Waste	.73 $MTCO_{2e}$/Ton
Food Waste	Food Services	.78 $MTCO_{2e}$/Ton
Fertilizer (Nitrogen)	Landscaping	.004 $MTCO_{2e}$/lb