CHARTING A PATH TO GREENHOUSE GAS REDUCTIONS

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Introduction

In response to student interest, Duke University administrators committed in 2004 to a greenhouse gas management plan. Following the completion of an inventory of the University's emissions since 1990, the Executive Vice President formed a committee of students, staff, and administrators to study the feasibility and cost of a wide range of potential emissions reduction measures. This paper describes the methodology employed and lessons learned by Duke staff and students in the process of implementing the University's greenhouse gas management plan.

Why should Duke reduce its greenhouse gas emissions?

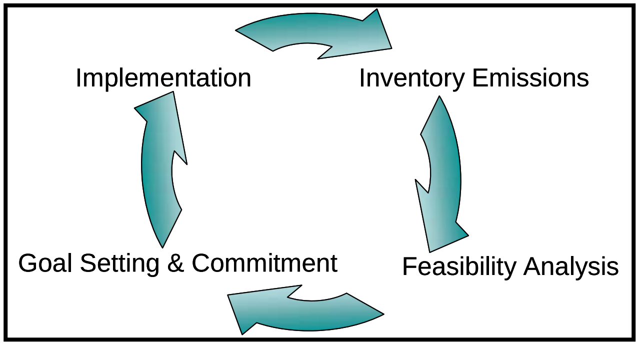
The question is often asked why universities should pursue greenhouse gas (GHG) emissions reductions. The Feasibility Study Committee identified six compelling reasons Duke should commit to reducing its emissions.

1. **Students want emissions reductions.** Across the nation and at Duke, students are organizing and demanding that their school act to slow global warming by reducing GHG emissions.
2. **Lead by example.** The scientific community is in general consensus that global warming is happening, is accelerated by anthropogenic GHG emissions, and poses serious threats to global stability. If Duke wishes to call for national and international actions that would limit these threats, it must be taking action itself.
3. **Educational / Research opportunities.** Solving the emissions problem requires bringing together the academic and operational sides of the university in a truly interdisciplinary partnership.
4. **Cost savings.** Substantial savings can be generated through energy efficiency.
5. **Hedge liability.** It is likely that future legislation will cap carbon emissions. Carbon reporting is already required in NC, in preparation for future regulation.
6. **It's the right thing to do.** While not all of the members on the committee agreed about the severity of the threat global warming poses, everyone agreed that minimizing human effects on the planet is simply a good idea.

Duke’s Greenhouse Gas Management Plan

From the very beginning, the students that approached the administration about reducing Duke’s GHG emissions intentionally asked for a commitment to a long-term management plan, not simply an inventory or a feasibility study. Working from the well established measure-plan-implement-measure strategic management paradigm, administrators and students developed and agreed upon a cyclical, four step management process (Figure 1). Initially, the process begins with an inventory of Duke’s emissions, which is followed by a feasibility analysis. The results of the feasibility analysis are reviewed by administrators and shared with the community in order to achieve buy-in and financial commitment. Finally, the measures recommended by the feasibility analysis are implemented.

Figure 1 - Duke’s GHG management process.



The process begins again each year, but not from scratch. The inventory and feasibility analysis are updated and changes are reported to administrators and the community. The implementation plan will likely not change dramatically from year-to-year as many of the measures will require multiple years to be fully implemented. However, it should change appreciably over a longer period, perhaps 5 years, as the implementation of highest priority measures are completed and lower priority measures are begun.

As Duke has just begun implementing this plan, the work described in this paper comes from Duke’s first pass through the initial two phases of this cycle.

Brief Inventory Methodology

Duke’s inventory was conducted during the summer of 2004 by a student in the 2005 class of Masters of Environmental Management at the Nicholas School of the Environment. The internship was funded and directed by Duke’s Environmental Sustainability Coordinator, with the support of the Facilities Management Department and Transportation Services.

Duke used the emissions inventory software distributed and maintained by Clean Air-Cool Planet, a non-profit organization based in Portsmouth, NH (Wilson 2004). Clean Air-Cool Planet’s online Climate Action Toolkit is a great resource for direction and case studies specific to emissions inventories on university and college campuses (Raynolds 2005). However, any campus looking to develop a comprehensive greenhouse gas management plan should consult the internationally recognized *Corporate Accounting Standards* developed by the GHG Protocol Initiative (WBCSD/WRI 2004). Compliance with the *Corporate Accounting Standards* will be necessary for any institution desiring to have their emissions mitigation claims verified in order to earn carbon credits from a carbon registry.*

Recognizing that the Kyoto Protocol has become the benchmark for environmental stewardship with regards to global warming, Duke's inventory includes emissions from all the fiscal years (FY) between 1990 and 2003, the last complete fiscal year at the time of the inventory. Some data were not available for all 14 years and had to be estimated on the basis of the data at hand. Consistent with the Kyoto Protocol, the inventory looked at emissions of six greenhouse gases: carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, HFCs and PFCs.

It is worth noting that because the intention was to establish a comprehensive greenhouse gas management program, the inventory process served two objectives:

> **Objective 1 -** Measure current and past emissions in order to identify trends, establish a baseline, and inform feasibility study.
>
> **Objective 2 -** Garner staff support for GHG mitigation through involvement, education, and *active listening.*

The relationships established during the inventory process proved invaluable when conducting the feasibility study. Anyone conducting a GHG inventory with the intention of implementing a management plan would do well to take the time to listen to and engage staff in the process, rather than simply query them for data.

Inventory Scope

Duke inventoried emissions from a number of sources both on campus and off, sources owned and operated by Duke and not, and offsets generated or purchased by the University. While Duke is not responsible for all of these emissions sources under the rules of the *Corporate Accounting Standard,* Duke inventoried them because it is interested in working to reduce emissions related to its operation even where it does not own the source.

The *Corporate Accounting Standard* defines three "scopes" for emissions inventories. The purpose of segregating emissions sources into these scopes is to avoid the double-counting of emissions reductions by multiple organizations. Table 1 describes the sources Duke inventoried within the three scopes. As the right hand column indicates, carbon credits generated by source reduction efforts on the part of Duke in Scopes 2 and 3 would accrue to parties other than Duke. Duke does not consider this a deterrent to addressing emissions in Scopes 2 and 3, but it is important to keep in mind if Duke decides to participate in a carbon registry (WBCSD/WRI 2004, pp 27-35).

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* Registries document and verify carbon emissions reductions in advance of a cap-and-trade program. The idea is that organizations which take early action to reduce their emissions will be able to receive carbon credits under a future cap-and-trade program if they register their emissions with a carbon registry.

Table 1 – Duke emissions sources by Scope and ownership.

	Source Definition (Corporate Accounting Standard)	**Duke Sources**	**Carbon Credit Ownership**
Scope 1	"owned and operated by the company"	Steam plant, Fleet vehicles, Refrigerants[1]	Duke
Scope 2	"emissions from the generation of purchased electricity consumed by the company"	Electricity purchase	Utility company
Scope 3	"emissions that are a consequence of the activities of the company, but occur from sources not owned or controlled by the company"	Employee and student commuters, Athletic team travel, Solid waste	Employees and students, Airlines, Landfill operator
Reductions	"GHG sequestration… offsets that have been purchased."	Duke Forest preservation, Wind power purchase	Duke, Undetermined[2]

[1] Duke uses R-409a, which has a global warming potential of zero, and only small amounts of HFC-134a, which has a global warming potential of 1,300. For this reason, the contribution of refrigerants to Duke's total greenhouse gas emissions is insignificant.

[2] Depending on various Renewable Energy Certificate definitions and the market in which they were produced, it is possible that carbon credits will be disaggregated and sold separately from the Renewable Energy Certificate (Holt and Bird 2005, 52-64).

Unit of Measure (MTCe)

The inventory results are reported in a unique unit of measure. Because each of the six greenhouse gases have different heat trapping potentials and remain in the atmosphere for varying lengths of time, each gas has a different global warming potential (GWP). For example, one molecule of methane (CH_4) released into the atmosphere will on average trap 21 times more heat than one molecule of carbon dioxide. Table 2 gives the GWPs for a number of GHGs commonly found on campuses.

In order to have a single unit of measure for expressing the combined global warming effect of an organization's emissions, the global warming contribution made by each of the gases is expressed in terms of the quantity of carbon dioxide molecules it would take to produce an equivalent amount of warming. The unit is eCO_2, or "equivalent carbon dioxide." For example, one molecule of methane

Table 2 – Global Warming Potentials for a number of GHGs.

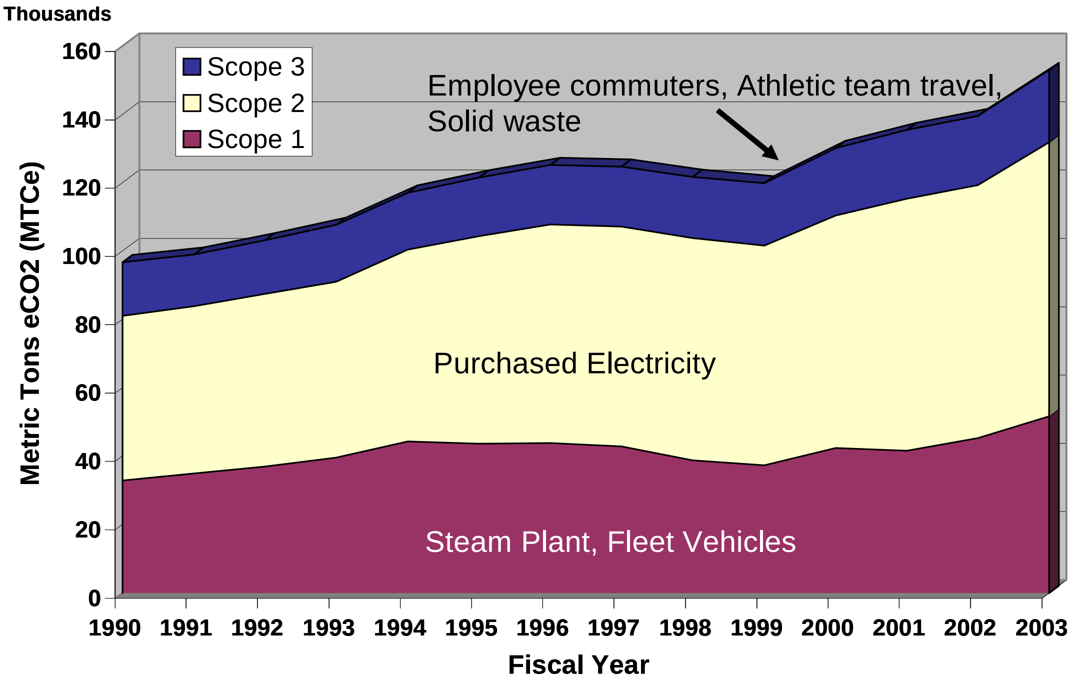
Chemical	100 Year GWP
CO_2	1
CH_4	21
N_2O	310
HFC-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001 (April 2003) EPA 430-R-03-004; Annex S	

would equal twenty-one eCO_2 molecules. The weight of the total number of eCO_2 molecules is summed to produce the unit used in this report: metric tons of carbon dioxide equivalents (MTCe).

Inventory Results[†]

The inventory included emissions related to the operation of the academic campus, medical center, clinics, and hospital. In FY 2003, the medical campus contributed 56% of the University's Scope 1 emissions and 60% of the Scope 2 emissions while making up 54% of the building space on campus. This reveals a trend that bears out over all 14 years of analysis: the medical facilities generate slightly more emissions per square foot than academic buildings. This may be a result of medical building codes that require energy intensive systems, such as once-through-air, advanced filtration, and steam sterilization. The final conclusion will have to wait because *the decision was made to focus the in-depth inventory analysis and feasibility study on the academic campus*. This decision reflects the on-the-ground reality that medical and academic facilities at Duke are operated by two independent facilities organizations. It made sense to administrators and staff to develop a complete greenhouse gas management plan for the academic side, test it, and then propagate it to the medical side. For this reason, the rest of this paper will address the emissions associated with the operations of the academic campus exclusively.

Figure 2 – Gross emissions for the academic campus, by Scope.



[†] While results from Duke's inventory and feasibility study are presented in this paper, it is important to recognize that these results are not comparable between campuses due to many factors that cannot be readily normalized (regional fuel supplies, transportation infrastructure, labor costs, location and climate, institutional mission, age of campus, etc.).

Figure 2 shows that between FY 1990 and FY 2003, gross emissions have risen 58% (using 1990 as the base year). Scope 1, 2 and 3 emissions rose 57%, 67% and 34%, respectively. The upward trend in emissions could reflect a growth in the energy intensity of campus life, a growth in the size of the institution, or a combination of the two. Normalizing the emissions as a function of building space helped determine what was driving this growth.

From Figure 3 below, one can see that emissions have stayed fairly constant in relation to building square footage. Indeed, the correlation between building space and the combined emissions from Scopes 1 and 2 is r=0.93. This suggests that the increases in the University's emissions over the last 14 years are closely linked to campus growth.

A regression analysis shows that the growth in electricity-related emissions has slightly outpaced the growth in building space, indicating increasing intensity of electricity use on campus. This is not surprising considering that air conditioning was installed in a number of older buildings during this time span, and all new construction has included air conditioning.

Some of the growth may also be due to the proliferation of plug-in electronic devices. However, it is not clear if the growth in the number of electronic devices on campus in recent years has resulted in a net increase in electricity usage. The devices manufactured in recent years are often far more energy efficient than those produced a decade ago thanks to improvements in technology, the emphasis on portable devices and efficiency standards being driven in the market by the EPA's ENERGY STAR™ program. Further study on the increase in plug-load usage is needed.

Figure 3 – Steam and electricity purchase emissions as a function of building space.

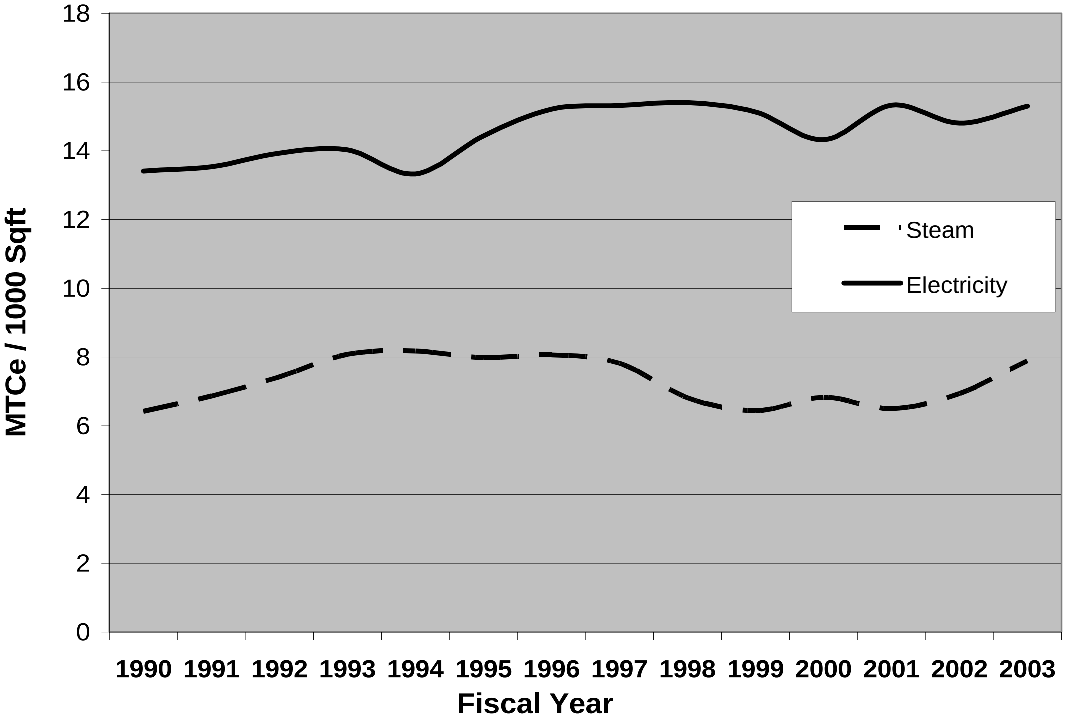


Figure 3 also shows us that steam usage per square foot dropped 20% between 1996 and 1999. This drop reflects the work of the Energy Management Team, which was operated by Facilities Management between 1994 and 1999. With a $3.5 million loan, the team completed 46 energy saving projects on campus, generating just under $1 million dollars in savings annually (Friedman 2004). While the Energy Management Team implemented measures that reduced demand for steam and electricity, the team's electricity work is not evident as a decrease in Figure 3 because much of it was offset by the construction of one of the largest electricity hogging buildings on campus, the 341,000 sqft Levine Science Research Center. Had Levine Science not been brought online during the same time, it is likely electricity demand per square foot would have decreased. Unfortunately, when the loan ran out in 1999, the Energy Management Team was disbanded and has not been restarted.

Emissions Offsets

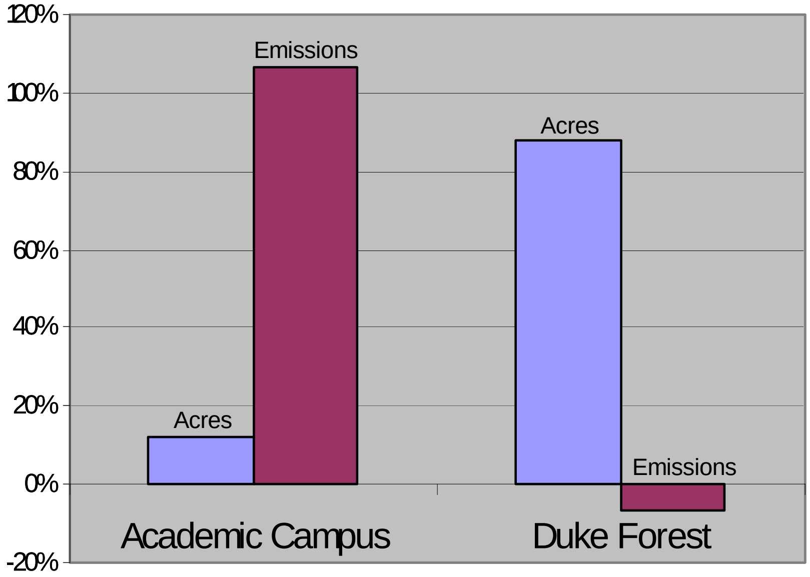
There are two kinds of emissions offsets: those that absorb greenhouse gases out of the atmosphere and those that stop emissions from being released that would have been released into the atmosphere under business-as-usual. Duke has two offsets it can take credit for, one of each type.

The Duke Forest consists of approximately 7,900 acres of farmland that the University has allowed to reforest over the last 75 years. A large portion of Duke Forest is registered with the state for preservation, and the University's forest management practices are certified as sustainable by both the Forest Stewardship Council and Sustainable Forestry Initiative (Cubbage et al. 2003). Thus, the likelihood that the carbon absorbed by the forest will be re-released through clearing or a major forest fire is unlikely.

William Schlesinger and Judson Edeburn, researchers in the Nicholas School of the Environment, estimate that the Duke Forest absorbs carbon from about 8,000 metric tons of carbon dioxide molecules each year. Compared to the 145,505 MTCe emitted by campus operations, that is not much. For Duke to offset all of its emissions through forest preservation, it would need to buy 139,500 more acres of forest.

It is remarkable that the energy

Figure 4 – Proportion of emissions and acreage contributed by the academic campus and Duke Forest.



intensity of activity on the academic campus, which is less than 1,000 acres, would so significantly outpace the absorption of 7,900 acres of forest (Figure 4). This imbalance between the quantity of emissions produced in densely populated areas and the quantity of emissions that can be absorbed by vastly larger vegetated areas exemplifies the global warming predicament as a whole.

The second offset for which Duke can take credit is the purchase of wind power through Renewable Energy Certificates. In 2003, students launched the Duke Green Power Challenge. Through the challenge, the University purchased 2,500 MWhs of renewable energy from a wind farm in Wyoming. In that region, emissions of 0.39 MTCe are created with each MWh of electricity, on average (Wilson 2004). Because wind power produces no emissions, the University can take credit for having offset 975 MTCe.[‡]

When these two offsets are taken into account, the *net emissions* for the University in FY2003 were 136,397 MTCe. The average car would have to drive 335 *million* miles to produce that amount of greenhouse gas emissions (Wilson 2004).

Feasibility Study

In January 2005, a committee formed by the Executive Vice President began to examine the potential for greenhouse gas emissions reductions as part of Duke's commitment to environmental sustainability. The group's primary goal was to research the cost implications of any greenhouse gas reduction targets Duke may consider. The committee met once a month for 5 months. Most of the committee's work was accomplished by individuals and subcommittees outside of the monthly meetings. The monthly meetings focused on methodology coordination and feedback.

Table 3 - Feasibility Study Committee members

Facilities Management Department	
Glenn Reynolds	Interim Director
Aurel Selezeanu	Assoc. Director
Dennis Kennedy	Steam Plant Director
Parking & Transportation Services	
Catherine Reeve	Director
Peter Murphy	Assistant Director
Medical Engineering & Operations	
Robert Guerry	Director
Students	
Johanna Jobin	Masters Env Mgmt
Becca Ryals	Masters Env Mgmt
Michael Thornton	BS in Mechanical Engineering
Office of the Executive Vice President	
Sam Hummel	Sustainability Coordinator

The committee comprised both students and staff (Table 3). While a wide variety of faculty members were consulted regularly throughout the process, no faculty served on the committee. There is no question having faculty representation on the committee would have been beneficial.

One of the unforeseen benefits of this committee was the opportunity to hear student, staff and administrator concerns and *address them in a non-public forum*. From the beginning of the 5 month process to the end, there was a dramatic

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[‡] This assumes that ownership of carbon credits is transferred with the purchase of Renewable Energy Certificates. For a discussion of the issues involved with this assumption, see Holt and Bird 2005, 52-64.

shift in attitudes towards the importance and benefits of GHG management. Staff who initially saw GHG management as extra work came to appreciate it as a way to improve best practices while doing something good for the environment. Students who were initially skeptical of the University's commitment to GHG management developed a sense of appreciation for the difficulty of the task and the earnestness with which staff and administrators were approaching it. It is unlikely this kind of a shift could have been achieved without the feasibility study process.

Analysis Methodology

The committee reviewed the feasibility and cost of more than fifty emissions mitigation strategies. (See list in Appendix A) Immediately, the group encountered the question of how to compare the relative benefit of strategies as diverse as increasing carpool incentives and burning more natural gas in the steam plant. The committee solved this problem through the Cost/Offset Ratio.

Cost/Offset Ratio

The committee recognized that its ultimate challenge was a maximization problem: What mitigation strategies would bring the University the greatest emissions reductions per dollar invested? When solving maximization problems, it is often helpful to use a ratio to describe the various potential solutions. The committee developed the Cost/Offset Ratio to help identify the mitigation strategies with *the lowest cost per MTCe offset*:

$$\frac{\text{Net Present Value of the Cost Generated by the Measure}}{\text{Total GHG Emissions Offset Over the Measure's Lifetime}} = \frac{\$}{\text{MTCe}}$$

Calculating this ratio for each mitigation measure under consideration reveals the "dollar cost per MTCe offset through the implementation of the given measure." Ranking the mitigation strategies by their ratio, from lowest to highest, solves the maximization problem.

Calculating Cost/Offset Ratios

Net Present Value is an economic calculation used to estimate the value of future savings or costs in today's dollars. Expressing the expected costs of each mitigation measure in today's dollars is important because Net Present Value takes into account the time value of money. The calculation for the ratio's numerator is as follows:

$$Net\ Present\ Value\ of\ Cost\ = \sum_{t-1}^{lifetime} \frac{AnnualCost}{(1+DiscountRate)^{t}}$$

Where:

- *Lifetime* is the time period during which the measure will produce the emissions reductions entered in the ratio's denominator. The lifetime will vary by measure. A behavior modification project could have a lifetime of 1 year while a new chiller installation could have a lifetime of 25 years.
- *AnnualCost* is the amount of money that will be going out the door in each year of the measure's lifetime, as a result of implementing the measure. If a measure creates an annual *savings*, it should be included here as a *negative cost*.
- *DiscountRate* is the short-term Treasury rate. The short-term Treasury rate is commonly used in determining the present value of future cash flows. To be conservative and anticipate rising interest rates, the committee used 6% as the discount rate despite the fact that the current short-term Treasury rate was 3.75% at the time of these calculations (April and May 2005).

Calculating the ratio's denominator (the total GHG emissions offset over the measure's lifetime) generally involves summing the amount of fuel that will be saved in each year of the measure's lifetime compared to business-as-usual. The next step is to convert that amount into MTCe using conversion tables that show how many MTCe would be emitted by burning a unit of that fuel (USEPA 2003). In cases where the fuel is *replaced* by a cleaner burning fuel, the total emissions offset will be the difference between the MTCe that would have been emitted by burning the original fuel and what will now be emitted using the new fuel.

Example: Use a 25% blend (46,863 MMBTu) of natural gas in the steam plant during the summer when prices are lower. No additional equipment is needed. Assume the average gas price is constant for two years. What is the Cost/Offset Ratio?

STEP 1 – Calculating the Net Present Value

Initial Cost = $0
Cost of coal per MMBtu = $3.27
Cost of gas per MMBtu = $9.09
Additional Annual Operating Cost = 46,863 ($9.09 – $3.27) = $272,740
Lifetime = 2 years

$$\text{Net Present Value} = \frac{\$272{,}740}{(1+.06)^0} + \frac{\$272{,}740}{(1+.06)^1} = \mathbf{\$530{,}041}$$

STEP 2 – Calculating the Lifetime Reductions

MTCe coal = .096 per MMBtu
MTCe gas = .053 per MMBTu
Annual MTCe reduction = 46,863 (.096 – .053) = 2,015 MTCe
Lifetime eCO2 reductions = 2,015 x 2 years = **4,030 MTCe**

STEP 3 – Calculating the Ratio

$$\text{Cost/Offset Ratio} = \frac{\$530{,}041}{4{,}030} = \mathbf{\$131.51}$$

STEP 4 – Interpreting the Cost/Offset Ratio

This tells us that "Offsetting 1 MTCe through this measure will cost Duke $131."

Savings

There are a number of measures that generate an annual savings rather than a cost. For example, the initial investment in replacing incandescent lights with compact fluorescent lights will generally be recouped by electricity savings within a few years. The calculations presented above can easily represent measures that produce a savings by simply entering the savings as a negative cost. In the case of upgrading to a compact fluorescent light, the $3 saved each year on electricity costs would be entered as an annual cost of -$3.

When savings are entered as negative costs, some Cost/Offset Ratios will come out negative. If a Cost/Offset Ratio is negative, it means that "offsetting 1 MTCe through the given measure will *save* the university that much money."

Using the Cost/Offset Ratio to Compare Measures

As mentioned previously, the purpose of the Cost/Offset Ratio is to help determine what measures would offset the maximum amount of emissions per dollar invested. This can be achieved by ranking the various measures from lowest to highest according to their Cost/Offset Ratio. Implementing the measure with the lowest ratio will offset the most emissions per dollar invested. Implementing the measure with the second lowest ratio will offset the second most emissions per dollar invested. And so on. In general, an organization is going to want to implement the measures in that order, if the sole goal of implementing each measure is to reduce GHG emissions.

Feasibility Results and Analysis for Duke

Constraints

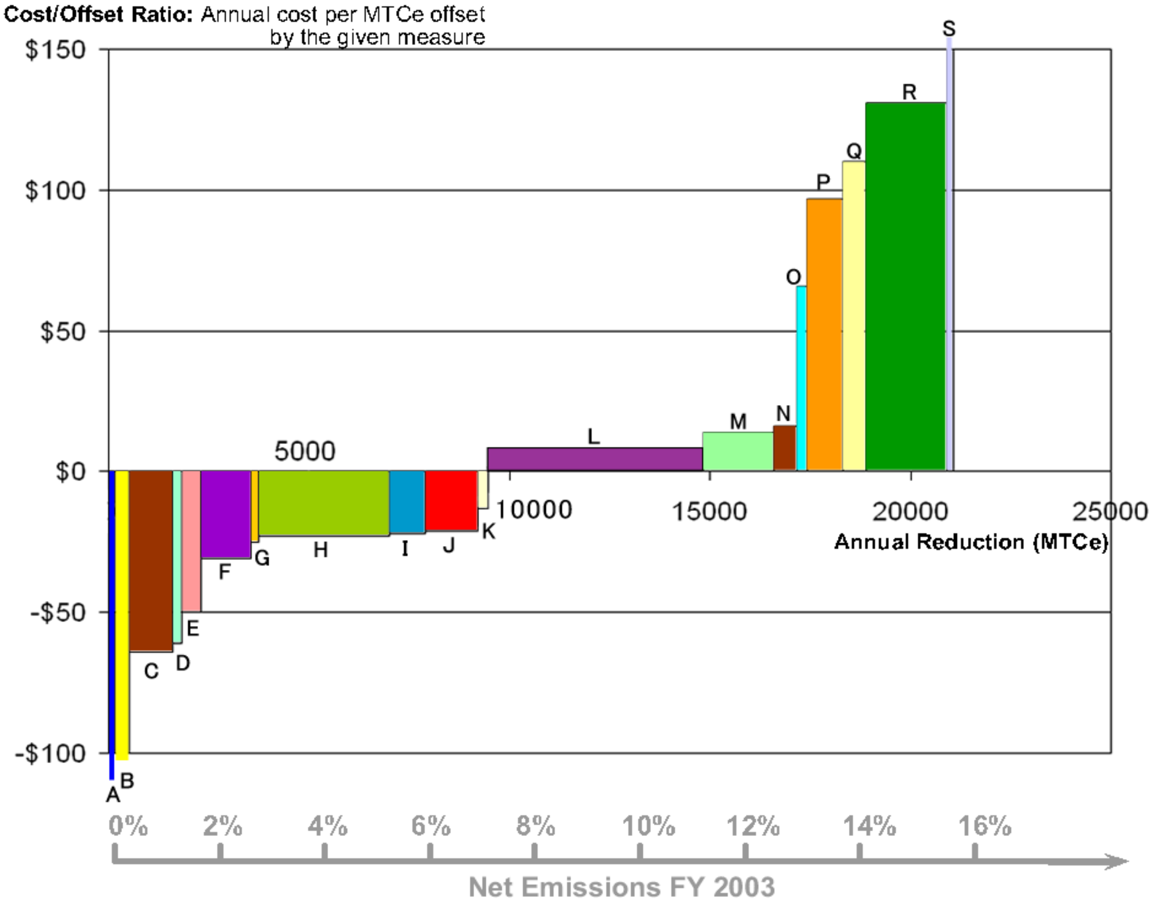
The committee quickly realized that it was not feasible to develop thorough cost estimates for a number of the measures under review in just five months. For example, adding cogeneration capacity to the campus' 75 year old steam plant is not possible due to space and capacity constraints already hampering the plant. Building a new plant that would use a cleaner fuel to generate both steam and electricity would make much more sense. However, the level of analysis required to determine the viability of building an entirely new plant would require far more time and resources than were at the committee's disposal.

Recognizing these time and resource constraints, the committee focused on a sample of the measures for which logistics and costs could readily be estimated (not necessarily a representative sample). The measures that could not be readily analyzed represent another level of research that the committee believes should be conducted. In presenting its results, the committee made it clear that it believes the results of the measures it was able to analyze warrant the expenditure of further time and resources on some of the more difficult but promising measures it was not able to fully analyze.

Interpreting the Results

The committee carefully thought about how to best present the various measures in order to easily communicate their relative preferability and cumulative benefit. Using the Cost/Offset Ratio and the Average Annual MTCe Reduction numbers for each measure, the committee came up with the visualization in Figure 5.

Figure 5 – Cost/Offset Ratios and Average Annual Reductions for 19 measures.



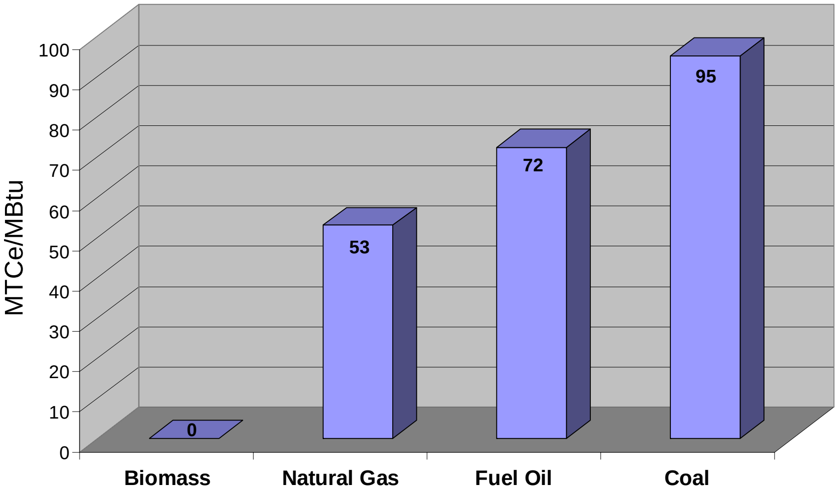
In Figure 5, nineteen measures are ordered left to right according their Cost/Offset Ratio, the magnitude of which is indicated by the vertical axis. Measures that extend below the horizontal axis have a negative Cost/Offset Ratio and would therefore save the University money. Measures that would not generate savings extend above the horizontal axis. The letters correspond to the measure details given in Appendix B. The width of the box representing each measure indicates the Average Annual Reduction expected over the lifetime of that measure. The numbers on the horizontal axis show the *cumulative* annual reduction achievable through implementing the stack of measures. For example, an annual reduction of about 15,000 MTCe would be expected if measures A through L were implemented. Another scale can be found across the bottom of the chart. This scale indicates the percentage of Duke's FY 2003 net emissions that could be reduced through the implementation of the stack of measures.

As can be seen from Figure 5, Duke could reduce its emissions by about 9,500 MTCe, an amount equal to 7% of its FY 2003 net emissions, simply by implementing the measures that will save money. If it were to implement all nineteen measures it would offset an amount slightly more than 15% of its FY2003 net emissions. To put that in perspective, the University would need to reduce its net emissions 44% below its 2003 emissions before 2012 in order to be in compliance with Kyoto. This was a discouraging realization for the committee. Fortunately, Figure 5 showed the committee where to look for more emissions reductions.

If Duke wants to reach Kyoto, it needs measures that will generate larger offsets. Figure 5 shows that some measures, such as A, B and D, produce big savings per MTCe offset but reduce emissions a relatively small amount. Other measures, such as O and S, have similarly small offsets but are relatively expensive. While these and the midsized measures, such as C, F, I, J, and M do add up, more than half of the cumulative emissions reductions found in this study came from just three of the nineteen measures (H, L and R).

All three of these measures involve replacing coal with a cleaner fuel source. Under Measure H, Duke would co-fire a 15% blend of biomass at the on-campus steam plant, which currently burns between 80% and 90% coal. Measure L is a 10.3 million kWh purchase of wind power from a wind farm in Kansas, where the utilities burn 40% coal (Aquila 2005, 16). And Measure R would have the on-campus steam plant burn a 25% blend of natural gas in the summer months when gas prices are

Figure 6 – GHG emissions intensity of various fuels (USEPA 2003).



generally lower. It makes sense that replacing coal would produce some of the most dramatic reductions. As Figure 6 shows, coal has the highest GHG emissions intensity of the four fuel sources commonly used in steam plants (USEPA 2003).

For decision makers, seeing the large reductions made by switching away from coal leaves a strong impression. It drives home the point that while “the cleanest watt of energy is the one you don’t have to generate,” Duke *cannot* achieve a 44% reduction in its emissions through energy efficiency alone. If Duke wishes to be a leader in curbing climate change, it must kick the cheap-coal habit and switch to cleaner fuels. From a strictly environmental perspective, the most benefit will come from combining the commitment to clean fuels with energy efficiency through cogeneration. As an example, Massachusetts Institute for Technology saw a 32% reduction in its GHG emissions when it brought on a new cogeneration steam plant in 1995 (MIT 2004).

Unfortunately, changing fuel sources is a complicated endeavor given that Duke’s current steam plant is primarily designed to burn coal (Figure7). Converting the steam plant to run on 100% biomass is not possible because of real estate constraints. Converting it to run entirely on natural gas will require running a multi-million dollar, high capacity pipeline to the campus, and putting the University at the mercy of a highly volatile fuel market. Building a new plant would allow more possibilities, including cogeneration, but determining the cost and feasibility of such a plan is far outside the capabilities of this study.

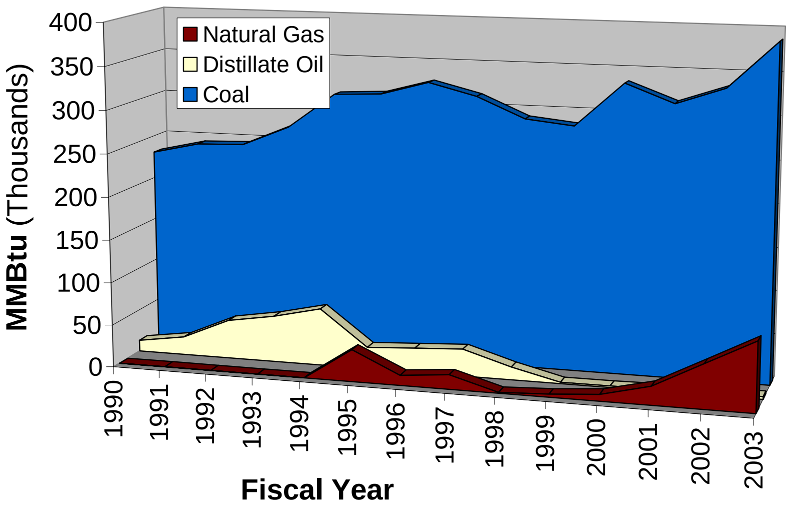


Figure 7 – Steam plant fuel use by thermal unit.

The picture is even more complicated when it comes to changing the fuel source for Duke’s electricity. Duke’s purchase of electricity is the school’s single largest source of emissions, at 55 percent. Duke could generate its own cleaner electricity in two ways. First, it could build a cogeneration plant that runs on a cleaner fuel. As mentioned above, the economic and logistical feasibility of such a plan requires further study. The second option would be to deploy alternative generation technologies such as wind and solar power. Neither of these are a good option, considering Durham does not have good wind resources and large-scale solar electricity generation is extremely cost prohibitive (see Measure S).

Duke’s off-site options for cleaning up its electricity purchase include trying to influence the local utility to burn less coal (if successful, the likely result would be more nuclear) or purchase emissions offsets through Renewable Energy Certificates (REC). While RECs seem like a good option, it is still unclear whether future carbon registries and trading schemes will in fact recognize RECs as carbon offsets (Holt and Bird 2005, 52-64).

As for energy efficiency, the savings justify themselves. Ten of the eleven measures that would save the University money were energy efficiency projects. The challenge with energy efficiency projects is not justifying their expense, it is establishing the operational and administrative roles necessary to ensure new projects are identified, funded, carried out and verified. This has been the experience at Duke, evidenced by the remarkable energy efficiency work done by the Energy Management Team in the mid-90's, and on other campuses: "While money is often cited as the primary impediment to efficient infrastructure management, there are actually many other impediments that are less apparent, the scarcity of (staff) time being the most significant" (Crowley 2005).

Conclusion

In the end, the committee found that it could not deliver the result it had been asked to deliver: a recommendation for a target emissions level and date, complete with cost and feasibility analysis. The problem was the 'complete with cost and feasibility analysis' part of the request. The committee could easily pick a reduction target and date, but guaranteeing that implementing the measures the committee identified would get Duke to that target by that date is currently impossible.

Despite all of its effort and research, the committee discovered there are still an enormous number of unknowns that need further investigation before the University could responsibly commit to an absolute emissions target. For example, a management plan must be developed in order to proactively address new emissions brought on by growth. The question of whether or not purchasing Renewable Energy Certificates entails ownership of carbon reductions must be resolved. A process must be agreed upon for establishing business-as-usual scenarios against which reductions can be measured. (This is especially true in the case of growth. What is the business-as-usual scenario for a green building when there is a campus-wide policy in place that says all new construction must be green?) Finally, the still-unfolding scientific analysis of black carbon's role in global warming could have a significant impact on our understanding of our global warming impact, and by extension, where we should direct our resources.

This is not to say the committee made no recommendations. It made a number of recommendations:

- At a minimum, the University should implement the measures that would save money.
- Savings from energy efficiency projects should be used to seed further GHG reduction projects.
- The University will have to stop using coal if it wishes to significantly curb its greenhouse gas emissions.
- Cogeneration and biomass should be heavily considered as options for a new steam plant.

- Operational and administrative roles need to be established to ensure that energy efficiency projects are continually identified, funded, implemented and verified.
- The University should participate in the debate over the relationship between carbon credits and Renewable Energy Certificates.

As a result of this process, a number of these measures are already being implemented. The discovery that the Energy Management Team had become defunct has resulted in a call for re-establishment, which should move a number of the energy efficiency measures forward. Some are being implemented regardless of this process. For example, insulating the steam pipes in manholes is a long overdue maintenance project. The staff loved discovering that a maintenance project they were planning on doing anyway was going to help Duke be a better steward of the environment.

Measures that are not yet being implemented, such as using biomass and cogeneration, are now being discussed in planning meetings with a seriousness and depth of inquiry not before present. There is no question the process has won a lot of people over. And in the rare case when it has not won a person over, it has not failed to impress upon them that thinking about global warming and greenhouse gas emissions is something Duke values.

Thanks to the committee's work, Duke is already realizing the validity of many of the compelling reasons the committee laid out for why Duke should tackle GHG management. Students are involved and enthusiastic about the progress the University is making. Duke is now in a position to participate in and even lead discussions with governmental bodies, businesses and NGO's that are developing greenhouse gas policies, regulations and markets. The committee's work has involved dozens of students, faculty and staff in an educational and research process that has already produced one Masters Project. Many cost saving opportunities have been identified and are being implemented. Should carbon emissions be regulated in the future, Duke will likely receive credit for its early actions to manage GHGs. And finally, many observers have noted that Duke's GHG work is just another example of how Duke always seems to "do the right thing."

Realizing the goal of major emissions reductions will require multi-year work and involve a broad range of participants inside and outside Duke. Fortunately, as a result of this process, Duke is well prepared to do that work.

Appendix A – Mitigation Strategies Reviewed

Transportation	***Electricity/Chilled Water***	***Steam Plant***
• eliminate freshmen parking • greater carpool incentives • 2 kinds of parking (“storage” and daily use) • incentives for people to live close to campus • further “green” campus fleets • hybrid SUVs for hospital and security • hybrid buses • bigger, but fewer, buses • stricter bus “no idling” policy • reroute buses to reduce number of stops • better bike paths on and approaching campus • Durham or Duke bus route to targeted, area apartments • increase parking fees • subsidize Durham bus passes for those that do not buy parking permit • fee-bate for those who do not buy parking permit • Car sharing: ZipCar, FlexCar • Reduce number of fleet vehicles	• Behavior modification • Building recommissioning • Steam driven chillers • Steam/Solar regenerated desiccant dehumidification • Restart Energy Mgt Team in maintenance shops • HVAC Heat Exchanger / Recovery for air intake • On-site Alternative Energy • Cogeneration • Solar street lighting • Night time computer/light shutoff • More day-lighting • More sub-metering for more efficient control • Energy Star purchasing policy • Building efficiency standards • More efficient transformers • More high efficiency lighting retrofits • Green power purchasing • Passive heating/cooling • Geothermal heating and cooling • Demarco-type geothermal systems	• Use more natural gas in summer when prices lower • Co-fire Biomass with coal • Build new biomass plant • Cogeneration • Improve monitoring systems / Energy management systems • Better control of room temperatures • Microturbines • Education programs: habit transformation • More sub-metering • Solar hot water • Solar steam collectors • Steam trap maintenance • Better insulation on system, particularly manholes • Better insulation in buildings • Improve insulation of windows on West Campus

Appendix B – Sample Measure Data for Duke

	Measure Name	Measure Description	Cost/ MTCe	Annual Offset	Scope
A	High Capacity Buses	Purchase 12 larger capacity buses during normal fleet upgrades to reduce the number of buses in service.	-$498	152	1
B	Transportation Demand Manager	Hire a Transportation Demand Manager and provide a budget to reduce single-occupancy trips to campus by 400 cars.	-$231	366	3
C	Education: Fume Hood Best-Use	Implement training for lab staff in energy-efficient use of fume hoods.	-$64	1088	2
D	Computer Energy Mgmt	Purchase and install Verdiem's enterprise computer energy management software on 1,500 computers.	-$61	225	2
E	Hybrid Buses	In addition to purchasing larger buses (already included above), purchase hybrid buses during normal fleet upgrades.	-$50	473	1
F	Chilled Water Upgrade	Perform piping corrections and other upgrades to one chilled water plant to reduce pumping power and other system losses.	-$31	1240	2
G	Dessicant Dehumidification	Install a dessicant dehumidification system in the renovation of Perkins Library.	-$25	199	2
H	Co-fire Biomass	Blend 15% wood-waste for co-firing in steam plant.	-$23	3258	1
I	Building Recommissioning	Based on historical evidence, a building recommissioning effort focused on several similar buildings would yield significant energy and cost savings.	-$22	899	2
J	Steam Turbine Chiller	Use excess steam capacity in the summer to drive a steam turbine chiller.	-$21	1321	2
K	Education: Dorm Energy Conservation	Expand the dorm energy conservation program already in existence on East Campus to West Campus.	-$13	245	2
L	Wind Power Purchase	This block represents the 10.3 million kWhs purchased by the Pratt School of Engineering in 2004.	$7	5373	2
M	Window Replacement	Replace 2000 single-pane windows on West Campus with custom-made double-pane windows.	$14	1758	2
N	Insulate Steam Lines in Manholes	A significant amount of energy is being lost where pipes are not insulated in manholes.	$16	585	1
O	Carpool/Rideshare Passes	Significantly decrease the price of carpool and rideshare passes to achieve 25 new carpools and rideshares.	$66	227	3
P	Solar Hot Water	Install a solar hot water system on the flat roof of the Bryan Student Center.	$97	925	1
Q	Natural Gas: 25% in Summer	Use a 25% blend of natural gas in the steam plant during summer months, when gas prices are lower.	$131	2015	1
R	Biodiesel	Increase the biodiesel blend in Duke buses by 30% to 50%.	$110	568	3
S	Solar Electric	Install a solar electric system on the flat roof of the Bryan Student Center.	$447	161	2

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