

# Carbon Offset Opportunities at the Duke University Health System



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OF THE ENVIRONMENT  
DUKE UNIVERSITY  
*forging a sustainable future*

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# Abstract

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Over the past century, global temperatures have increased in large part due to anthropogenic fossil fuel combustion. The impact of this change can already be seen in disappearing ice cover across the world. This trend has caused concern about the impact climate change will have on the environmental systems that civilization depends upon. Governments and other large bodies are acting now to address climate change; Duke University is among them. In 2007, Duke University President, Richard H. Brodhead, signed the American College & University Presidents' Climate Commitment, and made the pledge to be carbon neutral by 2024.

This master's project can aid the University in achieving its carbon neutrality pledge through the discovery of new and innovative carbon emission reduction opportunities within the Duke University Health System (DUHS). The opportunity exploration process consisted of: engaging in discussions with senior management, engineers, and staff; performing a broad literature review; and researching best practices at other institutions. Initial research areas identified were: energy efficient lighting, Energy Star equipment, sustainable medical and organic waste disposal, sustainable tableware, renewable energy, green purchasing, workplace transportation, and retrofits to existing buildings. After identification of the initial research areas, we reiterated the exploratory process and narrowed our focus to energy efficient lighting, sustainable organic waste disposal, sustainable tableware, and Energy Star equipment. In particular, the project focused on these areas within the boundaries of the Duke University Hospital (DUH) commercial-scale kitchen.

After exploring each of these options, several promising opportunities became apparent. The upgrades in lighting efficiency are most viable at this time, although several other opportunities are likely to become feasible in the near future. The results of the lighting analysis in the DUH kitchen revealed a total carbon reduction potential of 100 tons over the lifetime of the project and the hospital would realize annual savings of \$2000 in reduced electricity and maintenance costs. The results of the organic waste and sustainable tableware analysis are promising in terms of carbon reduction potential but prohibitive due to high costs. We recommend further analysis and collaboration with key stakeholders to discover strategies to reduce these costs. A broader application of lighting efficiency upgrades could further aid the University to achieve carbon neutrality, and simultaneously provide cost savings to the institutions involved.

# Acknowledgements

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# Acronyms

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BPI: Biodegradable Products Institution

CO<sub>2</sub>: Carbon dioxide

CO<sub>2</sub>e: Carbon dioxide equivalent

DCOI: Duke Carbon Offsets Initiative

DOE: Department of Energy

DUH: Duke University Hospital

DUHS: Duke University Health System

eGrid: The Emissions & Generation Resource Integrated Database

EPA: Environmental Protection Agency

GHG: Greenhouse gas

GSFL: General Service fluorescent lamp

H2E: Hospitals for a Healthy Environment

IESNA: Illuminated Engineering Society of North America

LCA: Life cycle assessment

LCOE: Levelized cost of energy

LED: Light emitting diode

MWh: Megawatt hours

NPV: Net present value

PE: Polyethylene

PET: Polyethylene terephthalate

PLA: Polylactide or polylactic acid

PP: Polypropylene

PS: Polystyrene

PVC: Polyvinyl chloride

WARM: EPA's Waste Reduction Model

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## **I. Introduction**

Over the past century, the global average temperature increased by 1.4°F and that upward trend is becoming more pronounced.<sup>1</sup> Current scientific evidence strongly indicates that greenhouse gas emissions from human activities are the main cause. If left unchecked, this upward trend in temperature could have large impacts on ecosystems and civilizations around the world. Due to these risks, governments and organizations across the globe are now focusing on methods to reduce greenhouse gas emissions. As a part of this effort, opportunities to reduce greenhouse gas emissions within the Duke University Health System were identified and researched.

## **II. Duke University Climate Action Plan**

In 2007, a total of 7,150 million tons of CO<sub>2</sub> equivalent was released into the atmosphere by the U.S. alone.<sup>1</sup> In that same year President Richard H. Brodhead signed the American College & University Presidents' Climate Commitment, adding Duke University to the list of more than 600 institutions pledged to take immediate steps toward carbon neutrality.<sup>17,25</sup> Recognizing the huge risk posed by climate change and the need for quick action, Duke University set the ambitious goal of achieving carbon neutrality by 2024.

Duke University's goal to be carbon neutral can be achieved in two ways: through the reduction of greenhouse gas emissions (GHGe) via on-campus projects and through the funding of off-campus projects that reduce GHGe. Duke University's Climate Action Plan stipulates that 45% of these reductions be met through on-campus projects and the remaining 55% through off-campus projects.<sup>25</sup>

## **III. Objective and Background Information**

The objective of our research was to identify carbon offset opportunities within the Duke University Health System in order to reduce GHGe; these opportunities could then be utilized by the University to achieve its pledge to be carbon neutral by the year 2024.

Two main clients or stakeholders were involved throughout the project: the Duke University Health System (DUHS) and the Duke Carbon Offsets Initiative (DCOI). The DUHS is composed of a number of buildings, both on and off campus as well as two other hospitals, Durham Regional and Duke Raleigh Hospital. The DCOI was established by the University to

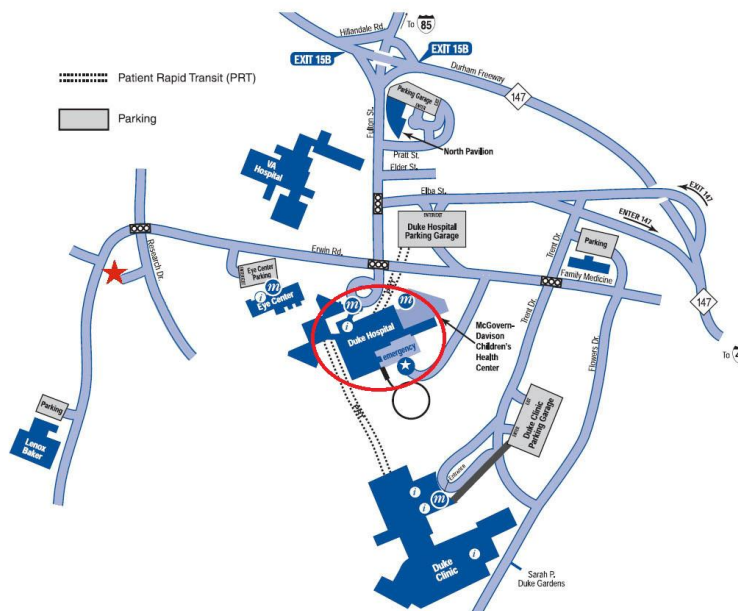
aid in achieving its carbon neutrality goal through the selection and funding of projects that are off-campus.

## Duke University Health System

The DUHS is a massive complex and some of its buildings are considered to be outside of the scope of the University. Our main area of focus within the DUHS was the Duke University Hospital (DUH), circled in the map below.<sup>23</sup> The DUH is considered to be off-campus; because the DUH is not included in the scope of Duke University’s Climate Action Plan, Duke University can fund projects within DUH and claim the carbon reductions achieved by those projects. Also, its large size and close location make it an attractive area to seek out carbon offset projects.

DUHS could benefit from participating in this project by gaining access to funds from the DCOI that would enable the implementation of more sustainable initiatives. There is also the inherent possibility of realizing long-term cost savings present in GHG reduction initiatives.

**Figure 1: DUHS Layout**



## Duke Carbon Offsets Initiative

As previously stated, Duke University can achieve its carbon neutrality pledge in two ways: reducing carbon emissions through on-campus projects or funding off-campus projects that reduce carbon emissions. The DCOI was established to identify, select, and fund the most attractive off-campus opportunities. The funding of off-campus projects is essential in meeting the University's goal because the cost of reducing on campus emissions by 100% is financially



infeasible. By funding off-campus projects the University will be able to meet its goal in a fiscally sound manner.

The DCOI could benefit from participation in this project by identifying more project opportunities to invest in, which would assist the University to reach its carbon neutrality goal by 2024.

## **DCOI Protocol**

### **Project Selection Criteria**

The DCOI follows a stringent project evaluation protocol to identify projects that are attractive investment opportunities to achieve carbon offsets. Carbon offsets are “the reduction, removal, or avoidance of GHG emissions from a specific project that is used to compensate for GHG emissions occurring elsewhere,” in this case Duke University Campus.<sup>72</sup>

The project must meet the following four criteria: real, measureable, verifiable and additional. For the project to meet the “real” criterion there must be assurances that it was or will be completed. The project must be measureable meaning that the amount of GHG emissions reduced can be quantified. The verifiable criterion means that the project could pass third party certification. Most importantly of all, the project must be additional, meaning that it would not have taken place without additional funding from the DCOI; in other words, it would not have taken place under a business as usual scenario.<sup>24</sup> Likewise, if the project is required to meet regulatory demands, it does not meet the additionality requirement. However, if an organization implements a project to comply with regulation and then implements even more stringent reduction measures, the criteria for additionality will be met.

### **Project Funding Criteria**

Once a project opportunity passes the four criteria listed above, a more in depth analysis can be completed to determine the amount of carbon that would be reduced and what the cost of the project would be. Upon completion of these analyses and if the project still looks attractive, the DCOI can provide funding for the project and in return receive carbon credits that count toward Duke University's carbon neutrality pledge. Carbon credits amount to permission to emit GHG, where one carbon credit represents the reduction of GHG equal to one metric ton of carbon dioxide. The shorthand for this metric is tCO<sub>2</sub>e, which stands for metric tons of carbon dioxide equivalent; this abbreviation will be used throughout the remainder of the paper.

In order to make the most efficient use of limited funds, the DCOI will only consider funding projects that require an incentive in the range of \$10-\$30 per carbon credit or tCO<sub>2</sub>e. This range is consistent with the market rate for voluntary carbon credits. Ultimately, the price that DCOI is willing to pay for a particular project depends largely on the characteristics of the offset project;

for example, a project that utilizes cutting edge technology to achieve carbon reductions far above the requirements would likely receive a higher price per carbon credit.<sup>37</sup>

The funding procedure will vary by contract. The DCOI has issued payments for carbon credits on both a monthly and annual basis. The DCOI will also consider providing capital funding under certain circumstances in the form of a “no interest loan.” In this scenario, the DCOI would provide the capital funding, the participating organization would pay the principal back over time, and the University would receive the carbon reduction certificates in lieu of interest payments.

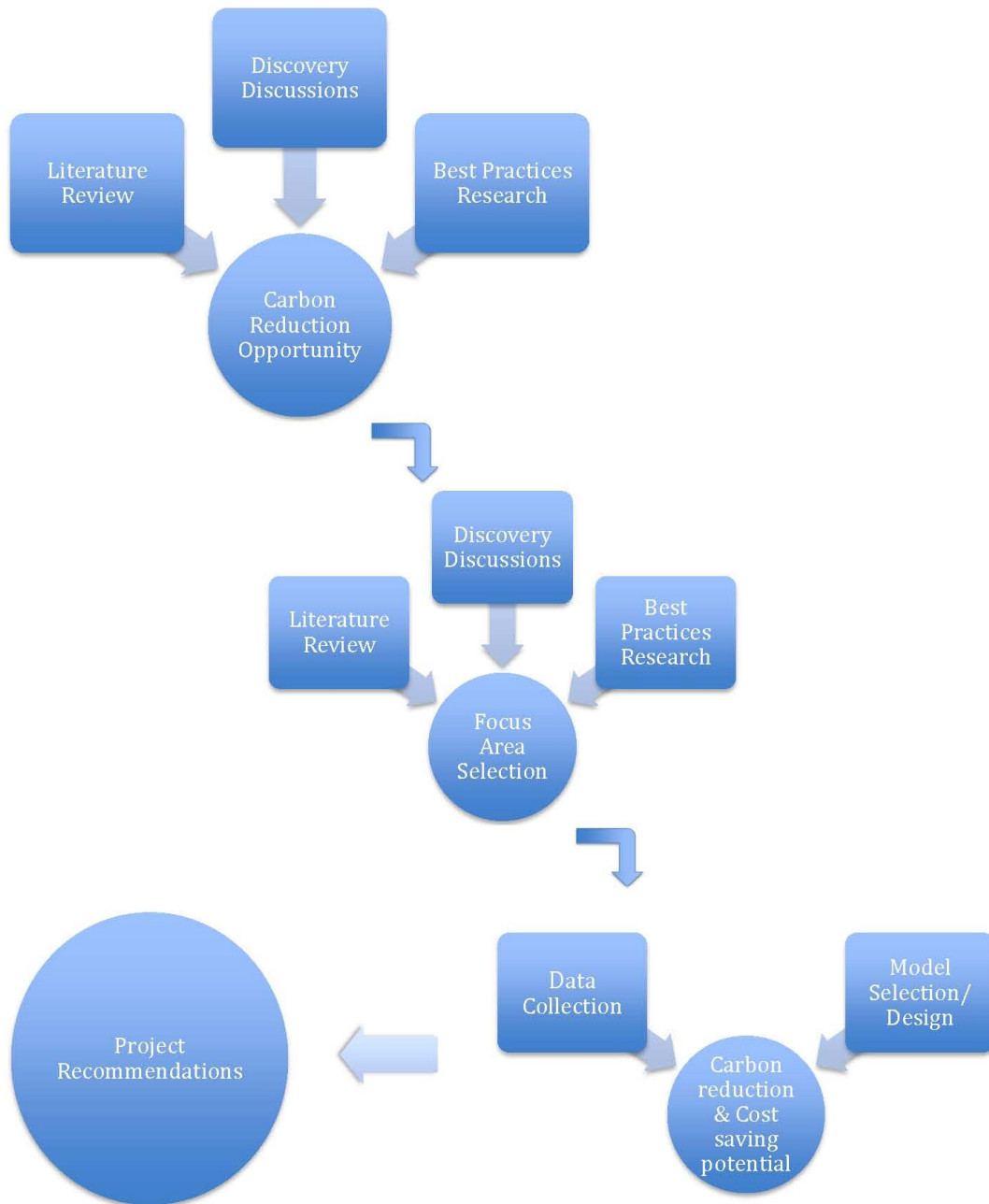
## IV. Methodology

The following is a broad overview of methodology (see Figure 2). A more detailed description of methodology can be found within the section on each focus area.

We began our project by engaging key stakeholders within the DUHS and DCOI. Within the DUHS we met with top executives, engineers, and construction design teams to discuss project goals and potential areas with carbon reduction opportunities. We identified a number of sustainable initiatives in which the DUHS was already engaged during this process as well. Concurrent with the discovery discussions, we performed a broad literature review and researched best practices in other institutions to identify potential opportunity areas. After this initial process we identified the following areas as having potential for carbon reduction actions: lighting, organic waste disposal, sustainable tableware, energy star equipment, medical waste disposal, renewable energy, green purchasing, workplace transportation, and LEED for existing buildings.

After we identified the initial opportunity areas we completed a second iteration of our initial process in order to narrow our focus. We reviewed the literature to discover carbon reduction projects that had already been completed in the areas of interest we identified above. We continued engaging with DUHS staff to identify which of the topic areas were of most interest to them and likely to result in the greatest financial savings and carbon reductions. We also researched best practices within other hospitals and buildings of similar scale. After completing this process, we identified lighting, organic waste disposal, sustainable tableware, and energy star equipment as our focus areas. These four focus areas were researched within the scope of the DUH kitchen. The commercial kitchen presented an attractive opportunity due to its size, long hours of operation, and present involvement in a large-scale renovation.

**Figure 2: Methodology**



Once the focus areas were identified, we began collecting data to quantify the carbon reduction potential within each project area. This process involved quantifying the amount of carbon currently being emitted to establish a baseline, identifying methods of reducing carbon, and then quantifying the reduction in emissions that would be possible if each method were implemented. To aid us in our analysis we researched the best tools available and incorporated GaBi (a life cycle assessment tool), EPA models, and custom-built Excel models in our final analytics.

Once we had the necessary data and modeling tools, we performed the data analysis and quantified the carbon emissions reduction potential present within each focus area. We next quantified the financial incentive that would be required from the DCOI to implement the project. Our final project recommendations to the DUHS were based upon total carbon reduction and overall cost of the project.

## **V. Current Sustainability Initiatives within the DUHS**

The DUHS has already undertaken various sustainability initiatives and been recognized on numerous occasions for its achievements. For example, in 2005, DUH became a partner with Hospitals for a Healthy Environment (H2E), a program formed jointly by the American Hospital Association, the U.S. Environmental Protection Agency (EPA), and Healthcare without Harm.<sup>5</sup> H2E's mission was to virtually eliminate mercury waste generated by hospitals, greatly reduce the volume of hospital waste, and identify new targets for pollution prevention and waste reduction.<sup>38</sup> As a result, DUH achieved a 95% reduction of mercury in its waste stream and collected and recycled 4,000 mercury-containing thermometers.<sup>6</sup>

DUHS has implemented other sustainability programs as well, such as replacing conventional wet mops with microfiber mops in several of their buildings. The switch has had the benefits of reducing water use, decreasing chemical use, and even improving hospital safety because the new mops are more sanitary than traditional mops.

Perhaps the most visible project to be implemented in recent years is the green heliport roof replacement project at DUH. During the project, 289,000 board feet of insulation were salvaged and reused elsewhere on Duke Campus, 430 tons of roof ballast stone were reused in road renovations in Duke Forest, and a total of 718 tons of construction waste were diverted from the landfill, avoiding 2,120 miles of transportation.<sup>80</sup> The new heliport roof has had a positive impact and has been welcomed by patients and hospital staff alike.<sup>42</sup>

## VI. Carbon Reduction Opportunities

In the US, more than 85% of total GHGe are CO<sub>2</sub> and 94% of these emissions come from fossil fuel combustion.<sup>55</sup> Methane accounts for another 8% of the total emissions.<sup>55</sup> Given that 93% of emissions are attributable to CO<sub>2</sub> resulting from fossil fuel combustion and methane release, we focused our efforts on identifying projects that would reduce emissions from these sources.

Hospitals in particular provide unique opportunities for GHG reduction because they have nearly 2.5 times the energy intensity and carbon dioxide emissions of a commercial office building, and thus may benefit from innovative energy efficiency and waste management strategies, resulting in long-term Operation & Maintenance (O&M) savings.<sup>30</sup> Oftentimes the main obstacle to implementing such projects is a high up-front, capital cost. Another obstacle unique to the healthcare environment is the imperative to adhere to strict regulations and protect patient health above all else; these requirements can outweigh the benefits of a carbon reduction project if the project comes with added risk to patient safety.

Given that the primary mission of DUH is to protect patient health and safety, extreme care was taken to pursue and research the carbon reduction strategies that would: have no detrimental effect on patient care; minimize disruption to hospital routine; give preference to current renovation and construction projects; and have significant and measureable carbon savings.

Keeping in mind the special concerns of a hospital environment, discussions began with the DUHS and DCOI and the following opportunities were identified as potential areas of carbon reduction within the DUHS:

- **Lighting**
- **Organic waste disposal**
- **Sustainable tableware**
- **Energy star equipment**
- Medical waste disposal
- Renewable energy
- Green purchasing
- Workplace transportation
- LEED for existing buildings

The top four opportunities listed were chosen as focus areas. To reduce carbon emissions associated with fossil fuel demand, we focused on increasing efficiency in lighting and commercial kitchen equipment; to reduce methane emissions we focused on improving organic waste disposal practices. Below, a brief summary of each core focus area is presented, followed by a brief overview of the remaining topic areas that were not further researched.

## Core Focus Areas

In accordance with criteria set forth by both the DUHS and DCOI and after a broad study of potential project areas, our team identified the following opportunities that have significant carbon emission reduction potential and meet the initial four criteria requirements to qualify for funding from the DCOI.

### *Offset Opportunities in the Duke University Hospital Kitchen Renovation*

The following opportunities presented by the current and ongoing DUH kitchen renovation were explored:

- *Kitchen Equipment Energy Efficiency Improvement*  
As part of the kitchen renovation plan, equipment including refrigerators, cold rooms, dishwashers, ovens, and ice machines were researched to determine if more efficient models were available than were scheduled for install.
  
- *Lighting Upgrade Opportunities*  
As part of the kitchen renovation, the lighting fixtures will be replaced and updated. The current plan includes T5 fluorescent lamps and fixtures; this paper examined the alternate possibility of installing LED lamps.

Additionally, in accordance with the Energy Independence and Security Act of 2007, T12 fluorescent lamp manufacture will cease in 2012. Therefore, DUHS is currently in the process of replacing all T12 lamps. This study examined the carbon footprint and associated costs of various lighting options.

- *Organic Waste Management*  
This study examined two alternatives to the current practice of landfilling organic kitchen waste: composting and anaerobic digestion.
  
- *Sustainable Tableware*  
The hospital kitchen has already made a partial switch to sustainable tableware and has expressed a strong interest in continuing this trend. The potential for carbon reduction opportunities within sustainable tableware was explored.

## Initial Project Areas Explored

### **Medical waste disposal**

Certain types of hospital waste require special handling and treatment prior to final disposal. Sharps are a good example of such waste. Sharps require special handling and disposal in order

to avoid potentially costly needlestick injuries; usually a third party waste management company that specializes in sharps handles the disposal. In 2011, DUH began reevaluating disposal options and requested proposals from three waste management companies for the management of sharps. In addition to requesting price information, DUH requested that the three companies provide the associated carbon emissions from the transport and disposal of the material; by doing so, it has sent a signal to the waste management companies and the community and earned DUH a green reputation.

Based on the Master’s Project on the Ambulatory Surgery Center at DUHS in 2011, the cost per pound for treatment of medical waste was \$0.19, and it was found that used sharps could be recycled to make new sharps.<sup>13</sup>

All three companies provided a statement of carbon emissions associated with their treatment technologies, processing site location and financial features. Technologies that support the reuse of sharps containers over multiple cleanings and reuse allow a very positive reduction in GHG emissions (see Table 1).

**Table 1: Medical Waste Disposal Proposal Summary<sup>22</sup>**

	<b>Current Practice</b>	<b>Company A</b>	<b>Company B</b>	<b>Company C</b>
<b>Loading Dock Service (Sharps)</b>	\$134,214	\$521,978	\$499,110	\$141,211
<b>Disposal Type</b>	Incineration	Autoclave	Autoclave	Recycled
<b>Disposal Location</b>	Haw River, NC	Concord, NC	<150m from campus	Creswell, NC
<b>GHG Impact (lbs of CO<sub>2</sub>e annually)</b>	—	976,000	800,000	14,080

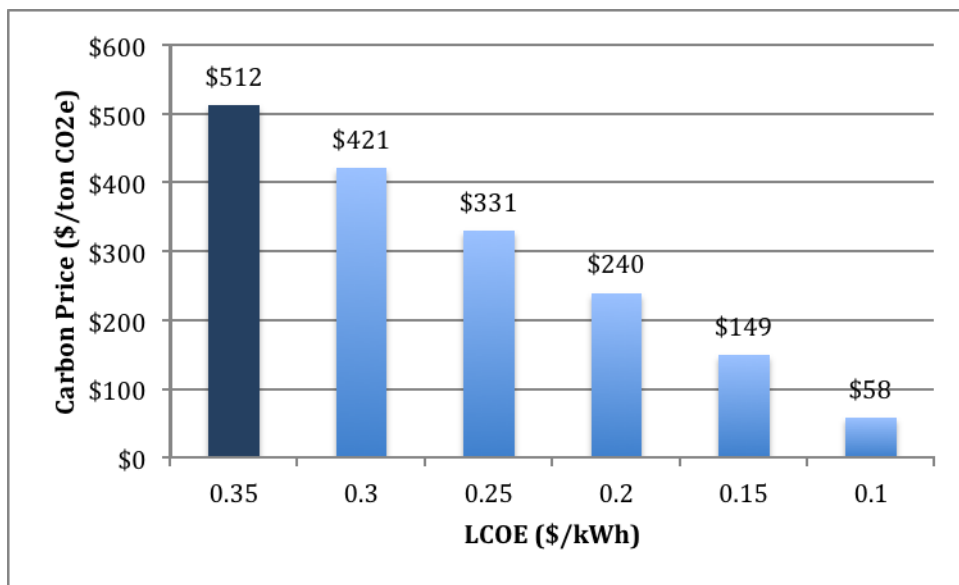
### **Renewable energy**

The installation of solar panels on the roofs of DUH buildings would be another way to reduce carbon emissions. The carbon intensity of energy produced by the solar panels is lower than that of electricity bought from Duke Energy.

In order to compare the prices of energy from two technologies, the levelized cost of energy (LCOE) is used. The LCOE includes upfront costs, installation, financing, and maintenance, and

distributes these costs over the lifetime of the panel. A comparison of the current cost of electricity bought from Duke Energy and the LCOE from solar panels gives the price differential that offset funding must overcome. Current estimates of the LCOE from solar panels in North Carolina are 0.35 \$/kWh, although some estimates are lower.<sup>9</sup> The current LCOE of solar panels places the per-ton carbon offset price out of DCOI's range (see Figure 3). One option DUH has, is to make new and renovated buildings solar panel-*ready*, in preparation for later installation when the prices of solar panels have sufficiently decreased. At that time, DCOI could reconsider funding the solar panels in exchange for the carbon credits.

**Figure 3: Solar Panel Carbon Price**



### **Green purchasing**

Given the success DUHS had with the partial replacement of conventional mops with microfiber mops in a number of its buildings, green purchasing certainly seemed like an area to be explored. Organizations like Practice Greenhealth promote sustainability through green purchasing practices as well. In our preliminary investigation, though, it became apparent that while the large size of DUHS and its subsequent purchasing needs would certainly hold opportunity for improving overall sustainability, many of the possibilities did not translate easily into carbon savings. Given the importance of locating and quantifying as simply as possible the carbon emission reduction potential within a possible program we were not able to delve deeper into this area, but we believe there is still great opportunity here for more sustainable practices in general.



## **Workplace transportation**

DUHS is a massive system and the DUH alone employs a large number of people that require transportation to and from work. That transportation is often by car, which is another large source of fossil fuel generated CO<sub>2</sub> emissions. Encouraging the use of public transportation and carpooling would certainly make a large impact on GHGe associated with DUHS if such a program were successful. However, two reasons halted further research in this area: the difficulty of implementing what amounts to behavioral changes on such a large scale; and the difficulty of quantifying carbon emissions that would be reduced and sustained by such a program given the large number of factors involved.

## **LEED for existing buildings**

DUHS currently requires all new construction to be built to LEED standard, but as a healthcare system with high costs, it is difficult to warrant paying the high price to undergo the extensive LEED certification process. We explored the potential for carbon offset opportunities in retrofitting existing buildings to LEED standard as well. While we believe that there are opportunities to be found in this area, again given the large number of existing buildings within the DUHS and the unique opportunities that would be found within each one, we decided that such research would not be within the scope of our limited time and resources. The opportunity remains to be explored, though, especially with the empty backfill space that has resulted from the creation of the new Cancer Center; this certainly presents an opportunity for renovations and upgrades before the space becomes occupied again.

## **VII. Carbon Offset Opportunities in the DUH Kitchen**

The DUH started a two-phase kitchen renovation and expansion in 2011 in response to an increasing demand for higher quality food services.<sup>21</sup> The implementation plan focused on decreasing water consumption, improving ventilation systems, upgrading lighting, and installing newer and more energy efficient kitchen equipment. After renovation, the food service system will be able to provide meals for the DUH campus including the Cancer Center and Duke Medicine Pavilion. Specifically, the Duke North Kitchen will expand its ability to serve patient meals made-to-order along with supplying the Duke North Atrium Caf é, Duke Cancer Center, Duke Medicine Pavilion, and Duke South Food Court. The renovation is scheduled to be complete by the end of 2012. At that point, the kitchen will switch to a room service model, which will increase patient satisfaction and reduce food waste; in addition, the food preparation and storage areas will be rearranged to improve kitchen flow.<sup>21</sup> The new kitchen will use a combination of relocated and new equipment.<sup>21</sup>

## 1. Lighting Upgrade Opportunities

The DUHS, like many other large institutions, is examining options for the replacement of their existing T12 fluorescent lighting systems. T12, T8, and T5 are fluorescent tubular lamps used in commercial and industrial settings. The number after ‘T’ refers to the diameter of the lamp, in eighths of an inch. As part of the Energy Independence and Security Act of 2007, the Energy Policy and Conservation Act was amended to encourage energy efficiency in lighting. In particular, it provided that the Department of Energy (DOE) design energy conservation standards to “achieve the maximum improvement in energy efficiency ... which the Secretary determines is technologically feasible and economically justified.” (42 U.S.C. 6295(o) (2) (A)) In 2009, the DOE issued the final rule on energy conservation standards for general service fluorescent lamps (see

Table 2). This rule places an efficiency requirement on fluorescent lamps manufactured after July 14, 2012.<sup>28</sup> The efficiency standard, given in lumens per watt, effectively bans the manufacture of T12 fluorescent lamps after this date.

**Table 2: Summary of the amended energy conservation standards for general service fluorescent lamps<sup>28</sup>**

(Refer to medium bi-pins for T12 and T8 lamps and to miniature bi-pins for T5 lamps)

Lamp type	Correlated color temperature	Energy conservation standard (lm/W)
4-Foot Medium Bipin .....	≤4,500K .....	89
	>4,500K and ≤7,000K .....	88
2-Foot U-Shaped .....	≤4,500K .....	84
	>4,500K and ≤7,000K .....	81
8-Foot Slimline .....	≤4,500K .....	97
	>4,500K and ≤7,000K .....	93
8-Foot High Output .....	≤4,500K .....	92
	>4,500K and ≤7,000K .....	88
4-Foot Miniature Bipin Standard Output .....	≤4,500K .....	86
	>4,500K and ≤7,000K .....	81
4-Foot Miniature Bipin High Output .....	≤4,500K .....	76
	>4,500K and ≤7,000K .....	72

T12 lamps comprise much of the lighting stock at the DUH. Currently, T12 lamps are still on the market and stockpiles of T12 lamps will likely be available for sale for a short time after the standards go into effect. However, eventually the DUH will need to transition away from T12 lamps to another lighting source. Options include certain T8 lamps, T5 lamps, and light emitting diode (LED) lamps, in generally increasing order of efficiency and average price. While a minimal upgrade in lighting is mandated by regulation, lighting decisions that go beyond the requirements may generate carbon offsets.

The cost differential between two types of lamps could be overcome by using outside funding to upgrade to more efficient types of lighting. The energy efficient lamps produce fewer carbon

emissions because the electricity that powers the lamps is produced, in part, by coal and other carbon-intensive fuels. The University may fund a more energy-efficient option than the DUHS would otherwise have chosen, with the differential in carbon reductions going to the University as offsets.

## Methodology

After touring the kitchen and reviewing the renovation plan, we found that the kitchen lighting was currently provided by T12 lamps and that over the course of the renovation, the light fixtures were scheduled to be replaced. The renovation plan specified an upgrade to T5 lamps, which are much more energy efficient than either T8 or T12 lamps. The design team had already gone beyond the minimum requirements in energy efficiency by choosing T5 lamps over T8 lamps. Further upgrade to LED was beyond the financial scope of the renovation. This gap created an opportunity for DCOI to fund the further upgrade to LEDs and acquire the carbon credits.

In order to determine if the cost differential between the T5 and LED would be acceptable to DCOI, we had to determine what input from the DCOI was necessary in order to make the LED option feasible for the DUH. To evaluate the lifetime cost of a fixture, we took into account the initial cost of the fixture, the labor cost to install it, the electricity cost, and the maintenance costs associated with parts and labor. Because the DUH uses a planning period of ten years, the costs were evaluated over a ten-year period. We developed an Excel model to compare the costs and carbon emissions of T5 and LED lighting options, taking into account numerous factors (see Appendix A for further explanations of factors discussed below).

When LEDs are used for general illumination, a role traditionally held by fluorescent lamps, numerous LEDs are placed in a strip that is the size and shape of a T5 lamp. An LED fixture is more expensive than a comparable fluorescent fixture, mainly because the LED fixture includes the LED lighting strips. The fixture cost for LEDs used in this model was \$310, approximately 1.5 times the cost of a T5 fixture.

The lifetime of the lamp was another important consideration as it defines the replacement rate. Beyond purchasing the replacement lamp, there is a labor cost associated with installing and maintaining it. Efficient kitchen management mandates a minimization of the frequency of required maintenance. T5 lamps have an average lifetime (30,000 hours) that is 50% longer than that of T12 lamps. Assuming the lights are on 24 hours a day, as may be expected in a commercial-style kitchen, this lifetime results in lamp replacement every 3.5 years, rather than just over 2 years. However, LED lamps may provide for even lower frequency of replacement, on the order of every 6 years, due to their lifetime of 50,000 hours.<sup>86</sup> LED lamps are more expensive up-front, but they may be more durable in the kitchen and will not need to be replaced as frequently. A longer lamp lifetime means that normal kitchen schedules would not have to be interrupted as frequently for maintenance and that the risk of accidents involving the lamps would be minimized. For example, there are user reports that T5 lamps break easily when they

are being replaced.<sup>51</sup> In a kitchen setting, cleaning up broken glass and electronics is even more of a concern than in general-use rooms. Lamp lifetimes were found on company websites and then compared to values in reports from the DOE for corroboration.<sup>28</sup>

In order to assess performance characteristics of the various lamps, we reviewed DOE studies that provided objective data on lumen output.<sup>54</sup> Lamp model options and prices (where available) were found at lamp manufacturers' websites. One important consideration was that while LED lamps have higher efficiency, they do tend to produce fewer lumens per lamp than fluorescent lamps do.<sup>78</sup> In replacement scenarios, this means that the spacing of the fixtures must be tighter for LED lamps in order to accomplish the same degree of lighting. This factor was taken into account in the model by applying a ratio to LED attributes such as costs and electricity use. Using this ratio allows the comparison of 1 T5 lamp to the equivalent of 1.1 LED lamps. In retrofit scenarios, the lighting needs of the space and the performance of the latest LED technology must be compared, since relocation of fixtures is generally not considered during a typical retrofitting effort. The carbon intensity of electricity used by the DUH, labor costs, and lifecycle carbon impacts were also taken into account (see Appendix A).

In order to determine a method for evaluating the financial impacts of the lighting options, we looked at several approaches. One method was net present value (NPV). The NPV method devalues cash flows that occur in the future, where the driving factor is the discount rate. Typically, a company has a planning horizon over which the cash flows are totaled. Another method to evaluate a project was the payback period. In this calculation, the undiscounted cash flows are compared to find the point in time at which the initial cost has been covered by subsequent savings or gains. Often, a company will only accept payback periods of less than three years.

After speaking with a financial representative at the Hospital, we found that a positive NPV with a discount factor of 9 to 12% over the ten-year planning period was required for a project to be considered feasible.<sup>20</sup> For the lighting options we evaluated, we applied the test of a sufficiently high NPV as well as calculating the payback period. If the NPV of a project was positive, even with the given discount factor, it met the 'hurdle rate' of the Hospital.

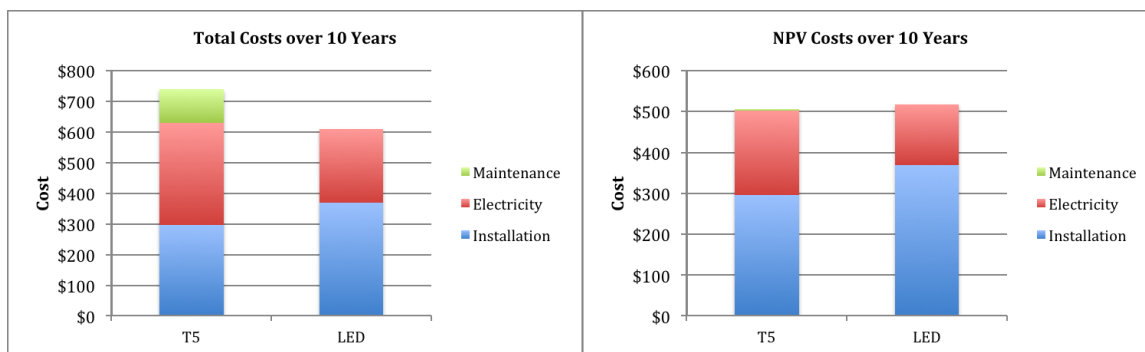
Applying the NPV approach to lighting, a person with a sufficiently high discount factor would not care if electricity costs were going to be high, as long as the up-front costs were low. As the discount factor decreases, the operating and maintenance costs matter more. Thus, an entity's discount factor assigns relative weights to the initial and the ongoing costs.

The output of the model, after comparing the costs and carbon emissions of T12, T8, T5, and LED lighting options, was the required financial incentive, in terms of dollars per ton of CO<sub>2</sub>e, which would be required by DUH to make upgrades financially feasible.

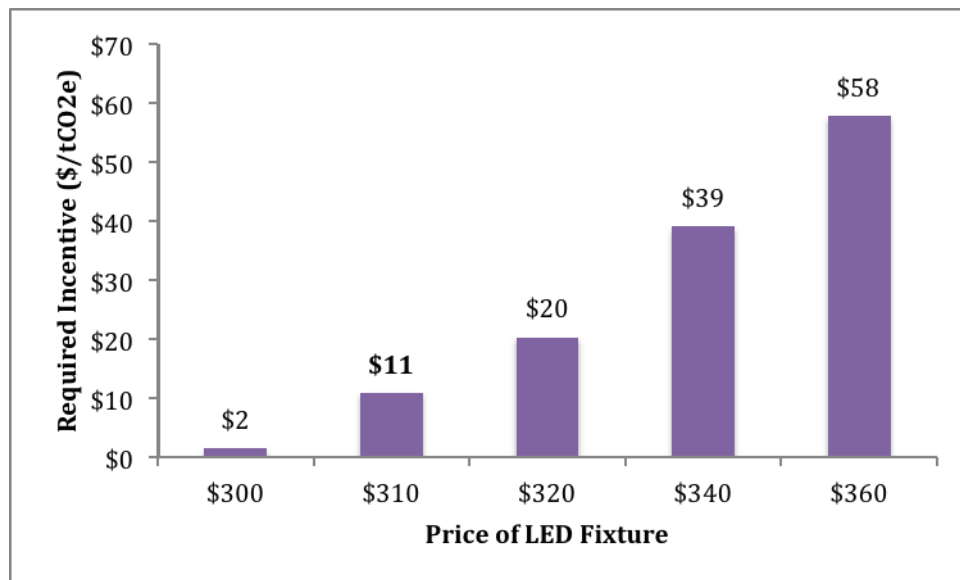
## Results

In the kitchen renovation, new lighting fixtures will be purchased to replace the old T12 fixtures. The initial renovation plan called for T5 lamps; however, we introduced LEDs as another option. A comparison of the costs to buy new fixtures and provide on-going maintenance showed the required incentive from DCOI to choose LED lamps over T5 lamps. While the total costs of LED lamps are lower than those of T5 lamps over 10 years, once the NPV of those costs are compared, LED lamps become slightly more expensive than T5 lamps (see Figure 4). Therefore, there is an opportunity for DCOI to fund the difference at an estimated rate of \$11 per CO<sub>2</sub>e avoided, for a total of 102 carbon credits for \$1,136 (see Figure 5).

**Figure 4: Cost Comparison**



**Figure 5: LED Incentive Analysis**



## Business Plan

There are several ways to set up the transaction between DUHS and DCOI. One is a simple payment per tCO<sub>2</sub>e reduced, with the rate calculated using the difference in NPV, as shown

above. However, this method does not take into account the fact that the budget for the kitchen renovation is pre-determined. Since the renovation has been planned for several years, the budget cannot be increased on short notice to allow for the higher cost of the installation of LED light fixtures.

An alternative transaction is a no interest loan. In this scenario, DCOI would loan DUHS a sum of money upfront to cover the increased cost of installation. Over a period of time, DUHS would pay back the loan. The annual installments would be less than the savings of labor and parts; thus, DUHS would be spending less each year than if T5 lamps had been installed. In lieu of monetary interest, the interest would be in the form of carbon credits. In addition, DCOI would recover the initial amount of the loan and be able to invest in further projects. The effective price DCOI would pay for the carbon credits would be equal to the opportunity cost of the loan; that is, the difference between the loan amount and the NPV of the loan repayments. A proposed transaction schedule is summarized below, with cash outflows in red and cash inflows in black (see Table 3). Annual payments and avoided costs are for each of the five years of the loan period.

**Table 3: Proposed Transaction Schedule**

	<b>DCOI</b>	<b>DUHS</b>	
<b>Initial Loan</b>	<b>(\$7,823)</b>	<b>\$7,823</b>	
<b>Annual Payments</b>	<b>\$1,565</b>	<b>(\$1,565)</b>	<b>x5</b>
<b>Annual Avoided Cost (average)</b>	<b>—</b>	<b>\$2,158</b>	<b>x5</b>
<b>Net</b>	<b>\$0</b>	<b>\$10,790</b>	
<b>NPV</b>	<b>(\$1,082)</b>	<b>\$9,157</b>	

The initial loan would cover the additional expense associated with installing LED fixtures rather than T5 fixtures, for the 106 fixtures planned for the kitchen. Over the next five years, DUHS would save an annual average of \$2,158 due to reduced electricity and maintenance costs. Each year, DUHS would repay an installment of \$1,565 to DCOI; after 5 years, the loan would be completely repaid. The NPV of the transactions, given DCOI’s discount rate of 5.5%, is -\$1,082. DCOI would receive 102 carbon credits, due to the carbon savings over the 10-year period; the rate is \$11 per carbon credit. This price is well within the \$10 to \$30 price range that DCOI is willing to consider. In addition, DUHS has a positive NPV of over \$9,000. Therefore, this arrangement would be beneficial for both DCOI and DUHS.

### **Discussion**

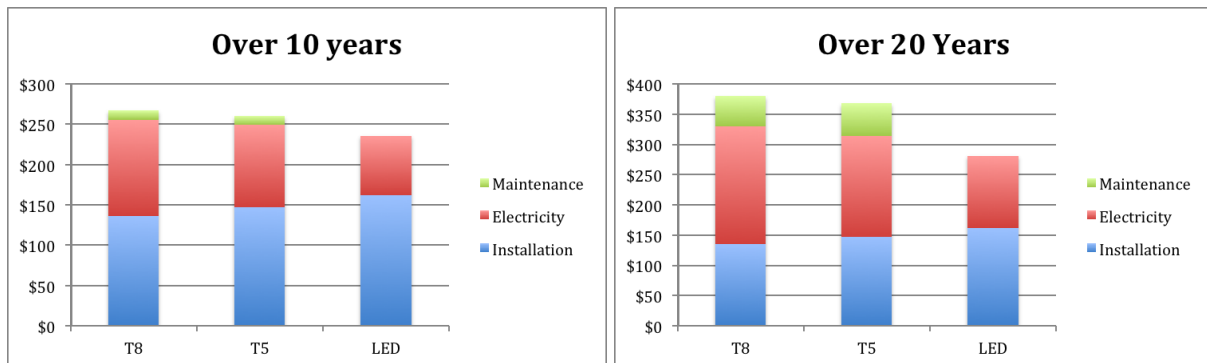
Based on our preliminary findings, the kitchen renovation team has requested a proposal for lighting by LED lamps, in addition to that of T5 lamps. Once the LED lighting layout plan is

developed, the number and cost of fixtures can be refined and the required incentive can be finalized.

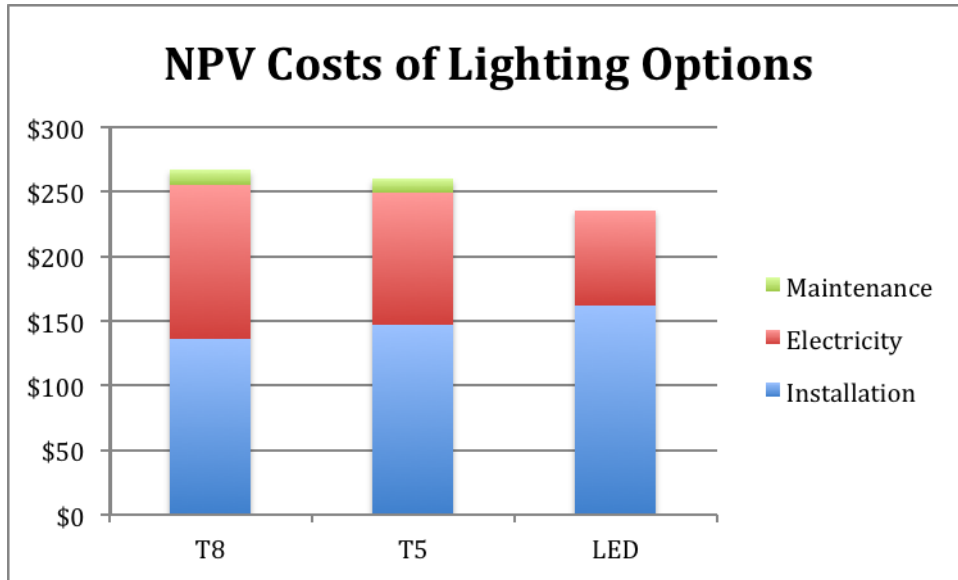
The finding from our lighting analysis will be useful not only for the kitchen, but also for other buildings in DUHS. In order to evaluate the lighting options in the research buildings at DUHS, we spoke with the Assistant Director of Engineering and Operations at the medical center, John Kramer, and his team of engineers. A walk-through of the research buildings showed that most of the current lighting was provided by T12 lamps, in a variety of fixture types and models. The fixtures varied a great deal in terms of ease of replacement and in appearance. John Kramer and his team pointed out which fixtures were most desirable to replace and which could simply be retrofitted.

Again, T12 fixtures may be replaced or retrofitted to receive T8, T5, or LED lamps; however, the cost of the installation kit for the LED lamp is higher than those for the T8 or T5 lamps. Fortunately, these higher up-front costs can be offset by reduced electricity and maintenance costs. Over ten years, the total costs associated with LED lamps are less than those associated with either T8 or T5 lamps (see Figure 6). Assuming daily usage of 12 hours, LED lamps will require replacement approximately every 11 years; these replacement costs need to be taken into account. Over twenty years, LED lamps are replaced but still have the advantage over the fluorescent lamps, although to a lesser degree (see Figure 7). Installing LED lamps, rather than T5 lamps, results in a payback period of 3.5 years.

**Figure 6: Comparison of Total Costs of Lighting Options**



**Figure 7: Net Present Value (NPV) Costs of Lighting Options (over 10 years for one fixture)**



A comparison of the NPV costs for a single fixture over ten years, using a discount factor of 10%, shows that LED is the preferable option when retrofitting existing fixtures. Since LEDs are financially preferable without added incentives, this may not be an opportunity for offsets. If DUHS and DCOI determine that LEDs would not be installed due to the higher upfront cost, even though the NPV is positive, a no-interest loan option could be considered for these buildings as well. In that case, the loan would range from \$10 to \$26 per fixture, depending on the exact upgrade, and the cost of a carbon credit would be between \$3 and \$6. In addition, DCOI may determine that since the renovation designs did not incorporate LED lighting options until suggested by this report, the upgrade to LED lighting still meets the additionality criteria.

In addition, since T12 lamps will no longer be manufactured after July 2012, Duke University will be undergoing a similar transition away from T12 lamps. The lighting analysis and model presented in this report may highlight optimal lighting choices for Duke University buildings as well, reducing the University’s carbon emissions and making it easier to meet the 2024 carbon neutrality goal.

## 2. Organic Waste Management

In the US, only a small proportion of food waste is recovered for waste-to-energy or composting: in 2009, only three percent of food waste was recovered. The cost of the remaining 97% was more than \$100 billion, including the cost of food over-purchasing, lost-energy, and waste disposal.<sup>36</sup>



Sending organic waste to a landfill ignores the remaining value of organic waste that could be harvested through proper treatment methods and unnecessarily contributes to global warming. Organic waste that decomposes under anaerobic conditions releases methane, which is twenty-one times more powerful than CO<sub>2</sub> as a greenhouse gas. To reduce that negative impact, many landfills have engineered systems to capture this methane and then flare or burn it before it enters the atmosphere. According to an EPA report, though, the methane from landfills still comprises 34% of all methane emissions nationwide.<sup>73</sup> In addition, the gases generated from landfills may pose potential health risks to local communities.<sup>7</sup> Reducing the amount of organic waste entering a landfill is the best method to reduce the quantity of methane being generated; this can be accomplished through the implementation of composting or waste-to-energy practices.<sup>71</sup>

The cost of sending waste to landfills is increasing due to stricter landfill regulations and the exhaustion of landfill capacity. As the cost differentials between other waste disposal methods and landfilling decrease over time, the decision to use alternative disposal methods is more likely to be financially feasible in the future.

### **Sustainable Opportunities**

At the present time, organic waste from the DUH is not recycled, with the exception of yellow grease (used cooking oil or fryer oil).<sup>12</sup> DUHS has contracted with Valley Proteins Inc., a subsidiary of Carolina By-Products Inc., to recycle yellow grease at no cost to DUHS.<sup>83</sup> Some of this grease is then turned into biofuel to be used as heating fuel for Valley Proteins' onsite plants. A hospital the size of Duke typically produces 26,000 lbs of fryer oil annually.<sup>50</sup> A total of 7.19 tCO<sub>2</sub>e are removed per ton of CO<sub>2</sub> emitted by the rendering facility, making the practice of recycling used fryer oil an effective carbon reduction strategy.<sup>82</sup>

In addition, DUHS has used the ValueWaste System, which tracks waste generation, to successfully implement source reduction and inventory control.<sup>12</sup> The system has the ability to track the sources of waste and calculate related costs by category of waste. With the help of this system, the kitchen has already reduced their weekly waste from 2500 lbs to roughly 1000 lbs.<sup>65</sup> In addition, the food department in DUH has already implemented waste separation for food waste, cardboard, and plastic products.<sup>19</sup>

Currently, the DUH kitchen has two pulpers, one in the patient service area and another on the retailer side.<sup>19</sup> A pulper is a large garbage disposal unit that grinds up organic matter, such as with water and then extract most of the moisture to produce a dry, organic pulp;<sup>45</sup> the water is then piped directly into the sewer line. This method greatly reduces the total volume and weight of waste that must be disposed of because food waste is approximately 75% water. Space is at a premium in a commercial kitchen and a pulper reduces the amount of space that would need to be allocated for organic waste storage if an organic waste disposal program were implemented. Through the use of a pulper, the generated pulp itself can be recycled 100%.<sup>60</sup> As part of the

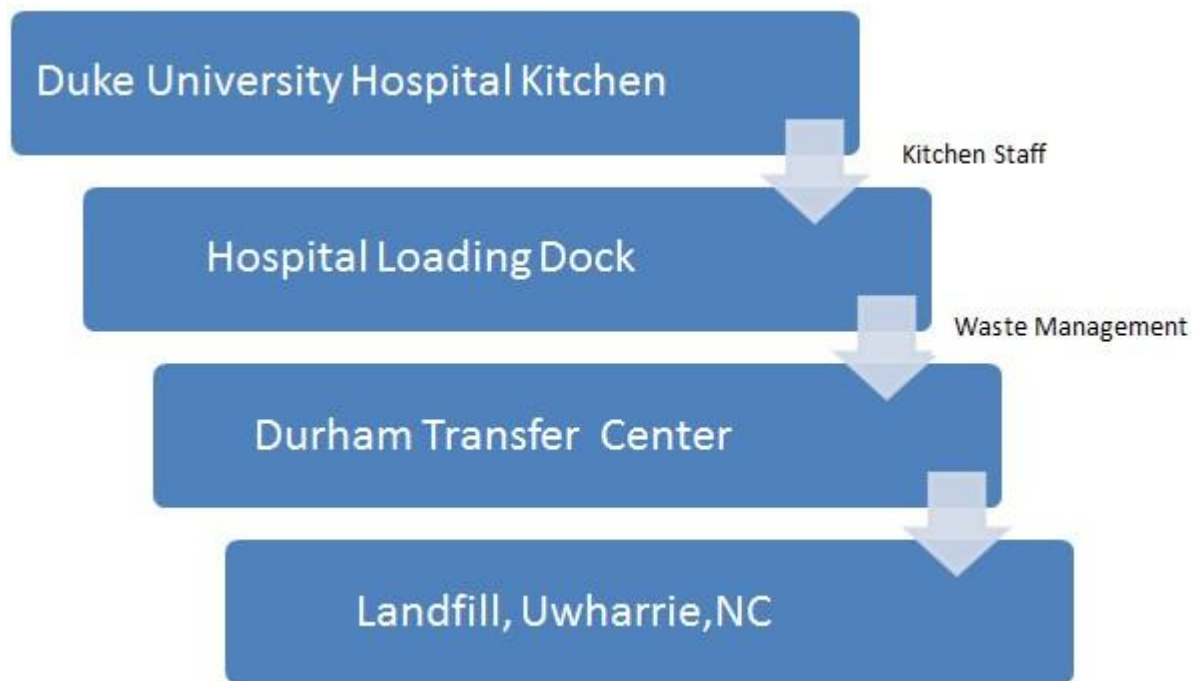
kitchen renovation plan, an additional pulper will be installed to reduce the waste volume in the Atrium kitchen.

### Current Practices: Landfilling

As mentioned above, landfilling organic waste produces a certain amount of methane. Based on the EPA Landfilling Emission Factor Framework, the net GHG emissions rate for landfilling kitchen organic waste is 0.69 tCO<sub>2</sub>e per ton of waste.<sup>35</sup>

In the DUHS, the organic waste is combined with solid waste, picked up by Duke Sanitation, and transferred to Durham Transfer Station before finally going to a landfill center in Uwharrie, NC (see Figure 8).<sup>18</sup> The landfill center does not have a methane capture system; thus, much of the methane produced will eventually end up in the atmosphere.<sup>18</sup> Alternative methods of disposal could minimize or eliminate this methane release.

**Figure 8: Flowchart of Organic Waste Treatment at DUH**



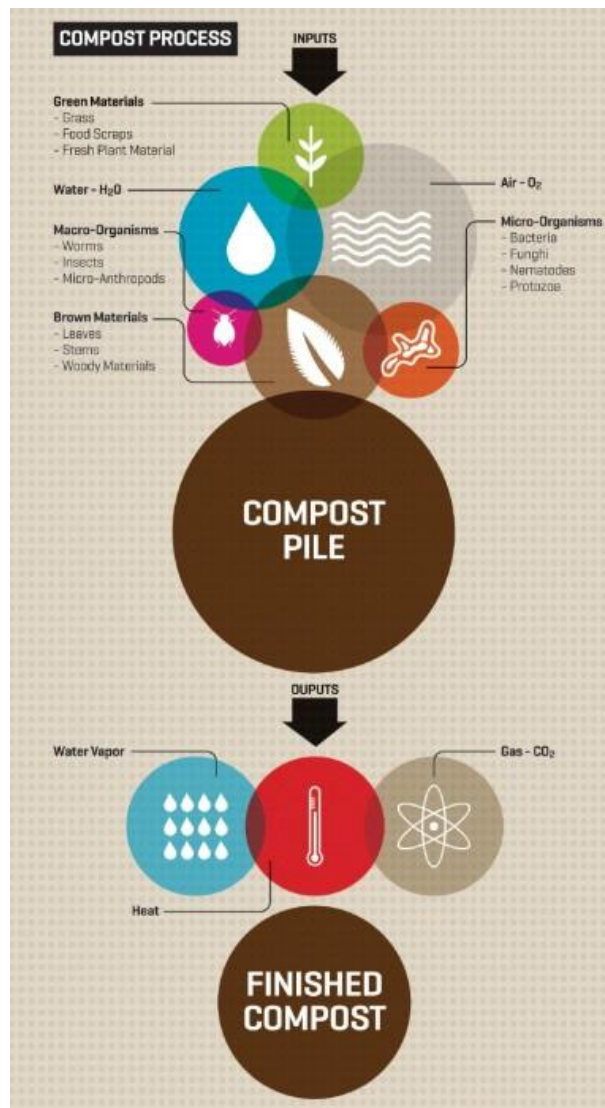
### Alternative 1: Composting

Composting accelerates the natural process of decomposition and returns the organic material to the soil. This enriched soil can be used as soil conditioner or fertilizer (see Figure 9).<sup>40</sup> As indicated in a study by the Department of Environmental Conservation of New York, compost can be applied to agricultural lands, recreational areas such as parks and golf courses, mined lands, highway medians, cemeteries, home lawns, and gardens.<sup>90</sup> Overall, composting has a net carbon reduction rate of 0.05-0.42 tCO<sub>2</sub>e per ton of waste composted.<sup>71</sup>

In addition to reducing GHG emissions, composting also diverts waste from landfills, which has several positive results. One result is the decreased production of leachate, which is liquid that has drained from the landfill and carries dissolved and suspended material.<sup>77</sup> Leachate can contaminate groundwater and transfer toxins across great distances.<sup>74</sup> Another result is a lessened strain on the steadily-decreasing landfill capacity: the number of active landfill facilities in the United States has fallen 79% since 1988.<sup>16</sup>

Based on an EPA study, the midrange cost for composting organic waste, including collection and processing, is estimated at \$72/ton nationally and at \$50/ton in North Carolina.<sup>64,61</sup>

**Figure 9: Composting Flowchart**



## Alternative 2: Anaerobic Digestion

Another method of waste disposal is through anaerobic digestion, a complex biological process that takes place in the absence of oxygen. Facilitation of anaerobic digestion usually involves a large, sealed, and insulated vessel, controlled temperatures, and bacteria supplementation.

During this process, biogas (mainly methane and CO<sub>2</sub>) is produced and captured in tanks for future use (see Figure 10). Anaerobic digestion is also known as biogas recovery in the US. A typical anaerobic digestion system consists of five components: an organic waste collection system, anaerobic digesters, biogas handling systems, gas use devices, and digester byproducts.<sup>32</sup> Each ton of organic waste that is anaerobically digested rather than landfilled prevents between 0.5 and 1.0 tCO<sub>2</sub>e from entering the atmosphere. The emissions reductions are both direct and indirect.<sup>81</sup> The direct emission reduction is derived from biogas capture and burning in place of atmospheric release. The indirect emission reduction is due to the avoidance of the GHGe by replacing a portion of fossil fuel energy generation with waste-to-energy processes.<sup>81</sup>

**Figure 10: Anaerobic Digestion Process**



In the US, the anaerobic digestion industry is emerging rapidly due to its significant environmental benefits and improving financial feasibility.<sup>81</sup> In particular, commercial livestock farms are well-suited to anaerobic digestion systems: as of December 2011, there were 176 anaerobic digester systems operating at commercial livestock farms in the US.<sup>2</sup> These systems generate more than 13 million MWh of electricity annually, which could reduce the need for fossil-fuel generation capacity by 1,670 MW.<sup>81</sup> In North Carolina alone, there are five digestion projects with a total capacity of 484 MW.<sup>2</sup>

## Business Plan for the Sustainable Treatment of Organic Waste

Consultation with the General Manager of Food Services, Ed Chan, revealed two concerns about implementing sustainable organic waste practices: additional labor requirements and extra use of space. One solution would be to contract with a third party waste management company. Based on the information collected during the tour of the Atrium Kitchen, the consumers voluntarily put plastic items in the correct recycling bin before placing leftovers on the waste line. The staff then further separates cardboard and organic waste before sending the latter to a pulper.<sup>19</sup> The pulped material is transferred to a compactor cart, which is taken down to the loading area on a daily basis. Therefore, contracting with a third-party recycling company would not require new behavior changes, additional labor, or extra space. DUHS staff would fill the compactors and transport the waste to the loading area as usual and then the contracted company would collect and haul it to the processing site at the contracted rate. If an organic waste collection bin in the kitchen were installed, it would be the size of a 55-gallon trashcan.<sup>65</sup>

There are several third-party composting or anaerobic digestion companies near Durham: Waste Management, Stanley Environmental Solutions Inc., and Full Circle Recycle NC (see Appendix B for a description of each company). However, the carbon credit flow would need to be clearly defined in the contract with the third-party disposal company in order for the DCOI to be able to claim the credits.

Additionally, there is an opportunity to donate excess food to a food bank. ARAMARK is currently developing a food donation program. According to Jim Larson, the ARAMARK liaison at the Food Donation Connection, many national and local food recovery programs offer free pickups and containers and the Bill Emerson Good Samaritan Food Donation Act (Public Law 104-210) protects food donators from legal liability.<sup>85</sup> Food donation not only provides food to populations in need, but also has potential for carbon emissions reduction.<sup>53</sup>

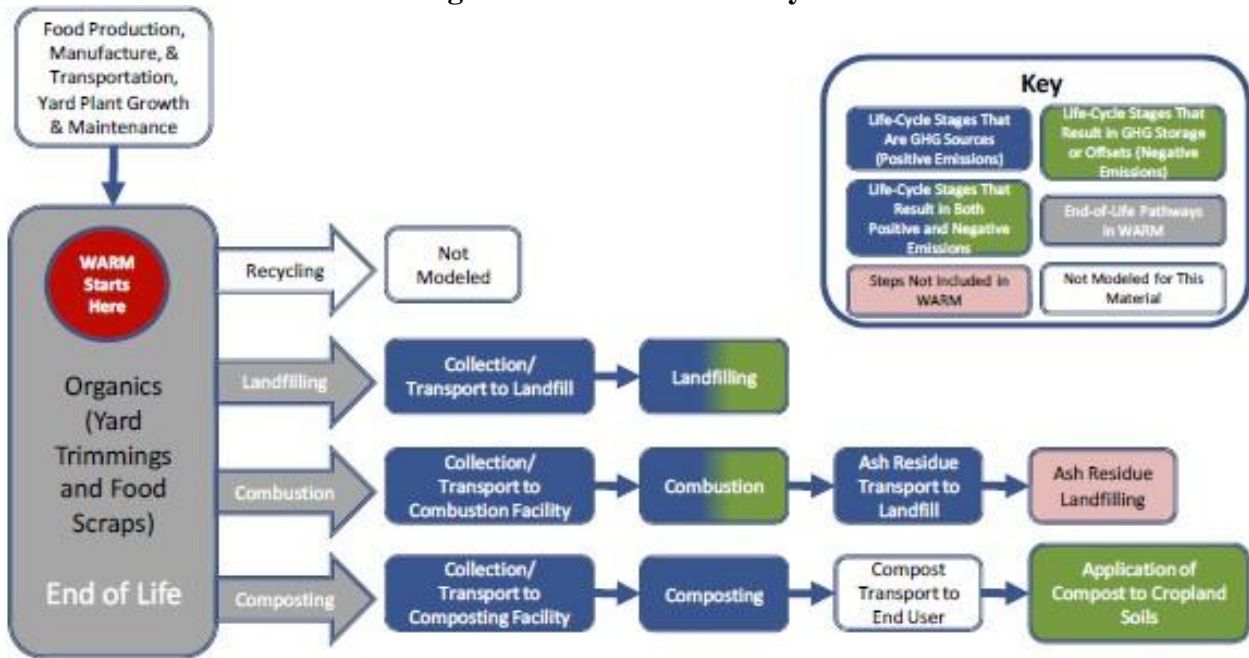
### Methodology

In our analysis, we used EPA's Waste Reduction Model (WARM) to compare various disposal scenarios and to estimate potential GHG emission reduction; EPA's food waste management cost calculator was used to evaluate financial characteristics for each scenario.

### WARM

WARM estimates the lifecycle GHG emission factors for organic waste from the point of waste generation to the point of waste disposal. It allows the user to compare GHGe under three material management scenarios: composting, landfilling, and combustion (see Figure 11).<sup>34</sup>

**Figure 11: WARM Pathway**



**Food Waste Management Cost Calculator**

Developed by the EPA, this tool estimates the financial characteristics of alternatives to food waste disposal, including source reduction, donation, composting, and yellow grease recycling.<sup>33</sup> The model develops alternative food waste management scenarios based on the waste profile and availability of alternative treatments, producing a cost comparison of the different scenarios.<sup>84</sup>

**Results and Discussion**

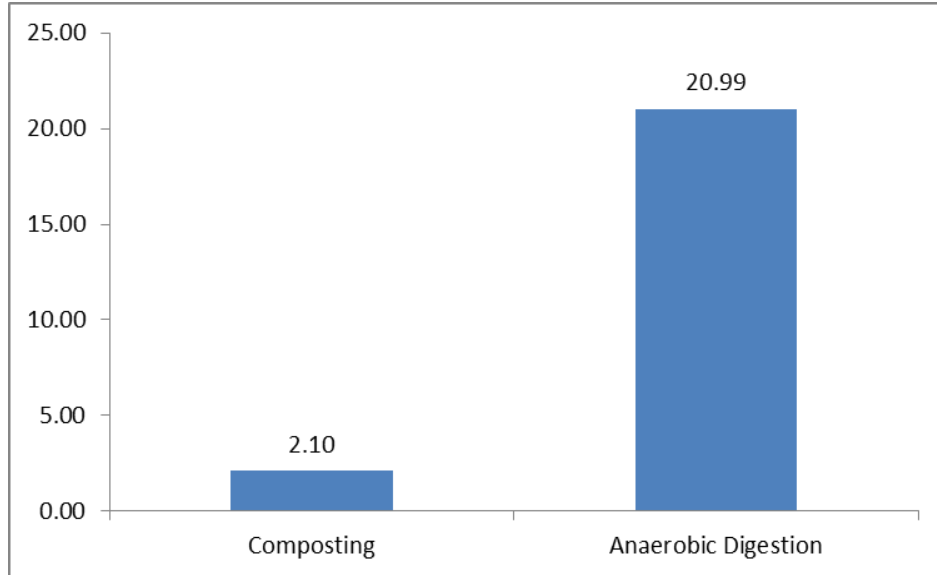
The current organic waste generation amount, according to the ARAMARK Waste Tracking Tool, is 230 lbs/day.<sup>44</sup> Assuming 8 pounds per gallon, this equates to about 29 gallons or roughly half of a 55-gallon drum.

Based on our analysis, the annual net carbon reduction potential for composting is about 2 tCO<sub>2</sub>e, whereas anaerobic digestion has the potential for about nine times that (see Figure 12). The difference in carbon reduction potential comes from the indirect carbon emission reduction of anaerobic digestion by substituting fossil fuel use with waste-to-energy processes in the electric grid.

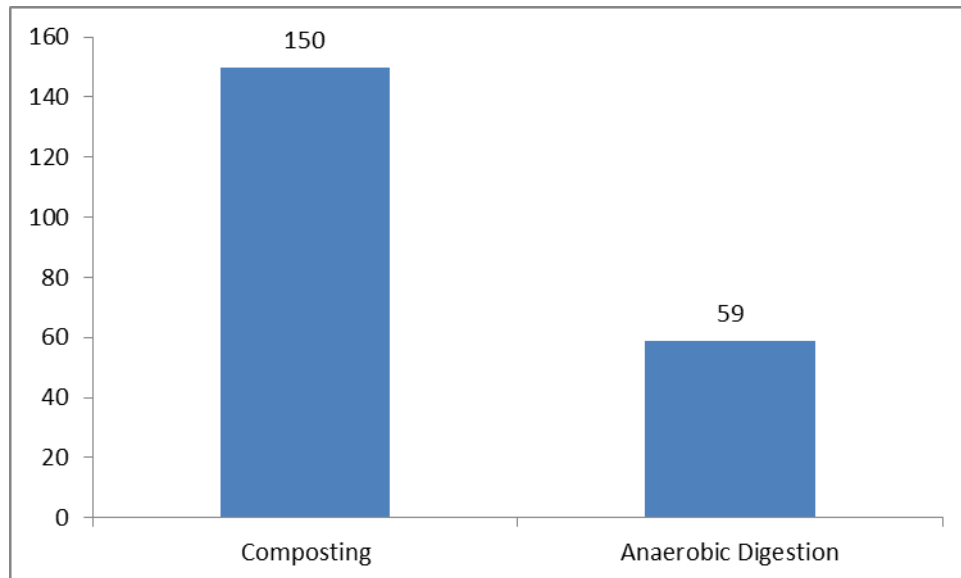
In terms of financial features, the model analyzed how much money DUHS has to pay for one additional ton of CO<sub>2</sub> reduction in each of these alternative scenarios. This parameter can also be defined as the required incentive from DCOI. The required incentive for composting is \$150/tCO<sub>2</sub>e, whereas the amount for anaerobic digestion is \$59/tCO<sub>2</sub>e (see Figure 13). These numbers are relatively high because the cost of waste treatment in North Carolina is low compared to other states. The higher incentive associated with composting is due to the limited

amount of carbon reduction. Therefore, our team recommends that anaerobic digestion would be a better approach for both DUHS and DCOI in terms of carbon offsets and financial feasibility; however, the final decision should consider the available waste management options and associated contract prices. If all sustainable waste management practices are found to be cost prohibitive at present, we recommend that such practices be revisited in the future. (See Appendix B for detailed calculations.)

**Figure 12: Organic Waste Net Carbon Reduction Potential Estimation (tCO<sub>2</sub>e/y)**



**Figure 13: Alternative Approach Required Incentive from DCOI (\$/tCO<sub>2</sub>e)**



### 3. Sustainable Tableware

#### Background

Hospitals typically go through large amounts of cups, plates, bowls and other tableware every day. Due to financial, space, and labor constraints, most hospitals do not utilize reusable tableware as they are more expensive and would increase labor needs by 80%.<sup>79</sup> Therefore, use of disposable tableware in hospitals is a common practice.

As the main food provider for DUH, the hospital kitchen uses large quantities of disposable tableware. Currently, the kitchen uses styrofoam plates, to-go-boxes, cups, and soup cups. Cup lids and straws are made of #3 plastic (PVC).

Styrofoam and PVC are not sustainable. Styrofoam is made from polystyrene, a petroleum-based plastic that is not biodegradable and never deteriorates.<sup>3, 4</sup> Also, it easily breaks into small pieces that can be dangerous to small children and animals. Based on a comprehensive study on PVC, the production of PVC is responsible for 40% of the world's chlorine gas consumption, with “hazardous, highly persistent, bioaccumulative, and toxic” byproducts.<sup>49</sup>

Alternative tableware materials allow for the recycling or composting of the containers after use. In addition, source reduction—minimizing the initial generation of waste—is an effective way to decrease waste. A success story from Starbucks demonstrates the promise of this option. In 2006, Starbucks switched to a paper cup with 10% post-consumer recycled fiber and also replaced the standard PET cold cups with polypropylene cold cups. In this way, Starbucks reduced its plastic consumption and associated GHGe by 45%.<sup>63</sup>

#### Sustainable Options

##### *Eco Products*<sup>66</sup>

Eco Products, a food service supplier, offers two lines of environmentally preferable products: GreenStripe® and BlueStripe™.

GreenStripe® uses sugarcane fiber, plant starch inputs, and polylactide (PLA), a thermoplastic polyester derived from corn; these components are mostly renewable and compostable.<sup>87</sup> All GreenStripe® products except Plant Starch Cutlery are compostable certified by Biodegradable Products Institution (BPI), which means that they can be commercially composted. However, not all of these products are suitable for hot foods.

BlueStripe™ uses post-consumer recycled PET plastic, polystyrene and fiber.<sup>27</sup> Using post-consumer recycled material gives a second or third life to the raw materials. The BlueStripe™ products perform as well as traditional plastic containers, but the production requires fewer



virgin resources and diverts waste from landfills. However, in contrast to the GreenStripe® line, not all products in the BlueStripe™ line are recyclable.

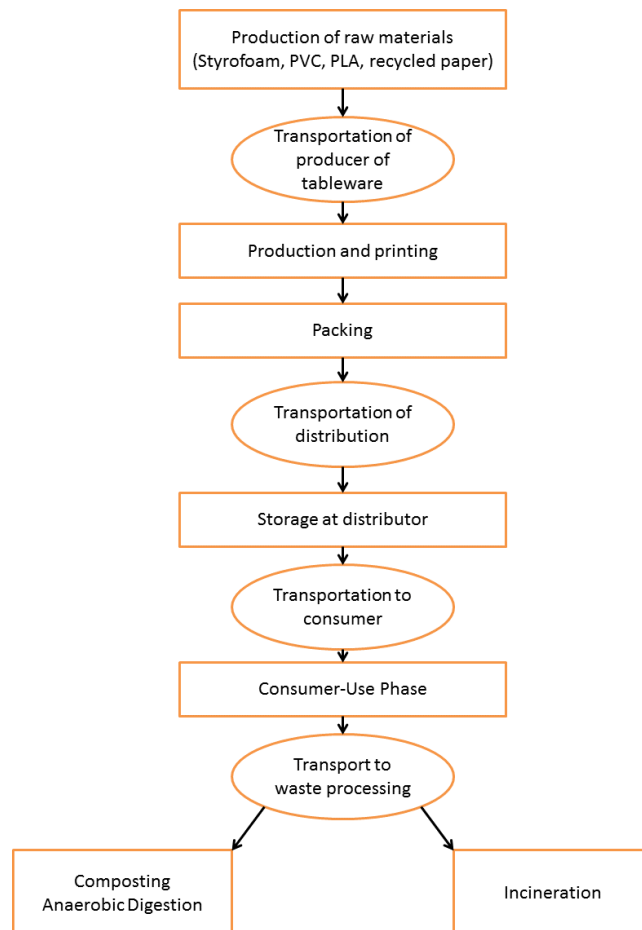
### **BIO-PLUS EARTH**

BIO-PLUS EARTH® uses 100% recycled cardboard, including a minimum of 35% post-consumer recycled paper content.<sup>26</sup> These products are compatible with a wide range of foods, including hot and wet foods. In addition, BIO-PLUS EARTH has been endorsed by the Green Restaurant Association, whose logo, printed on the bottom of each product, communicates to customers the organization’s environmental responsibility and sustainable efforts.

### **Methodology**

Our team used GaBi, life cycle assessment (LCA) software, to analyze the energy consumption and carbon emissions associated with styrofoam, PLA, and recycled paper. LCA quantifies the social, environmental, and economic impacts of a product over its lifespan, including the manufacturing, use phase, and disposal. Our analysis scope is illustrated by the following flowchart:

**Figure 14: Sustainable Tableware LCA Flowchart**



## Carbon Offset Potential

The hospital kitchen is currently using a relatively benign plastic, PVC, which is a thermoplastic made of 57% chlorine (derived from industrial grade salt) and 43% carbon (derived predominantly from oil and gas via ethylene).<sup>68</sup> It is less dependent on crude oil or natural gas than other plastics such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and polystyrene (PS), which are derived entirely from oil and gas.<sup>68</sup> DUHS is using the best-available plastic products already; therefore the best opportunity for DUHS to further reduce its carbon footprint would be to switch to products made from PLA or recycled paper.

World Centric has conducted an eco-profile study on various materials quantifying the resources, energy use, and associated economic and social externalities. The results show that both recycled paperboard and PLA products are more sustainable than styrofoam and PVC in terms of carbon emissions.<sup>11</sup>

Based on the information collected from Eco Products, most PLA in the US is Ingeo brand PLA, made by NatureWorks® which comes from 100% renewable resources and which is largely made in Asia, primarily mainland China and Taiwan.<sup>14, 56, 89</sup> The average carbon intensity from the electricity industry among seven main Asian PLA-producing countries is 0.79 tCO<sub>2</sub>e/MWh and this carbon emission rate affects the total quantity of carbon emissions associated with the manufacturing process. (See Appendix C for a detailed calculation.)

## Business Plan for Sustainable Tableware Introduction

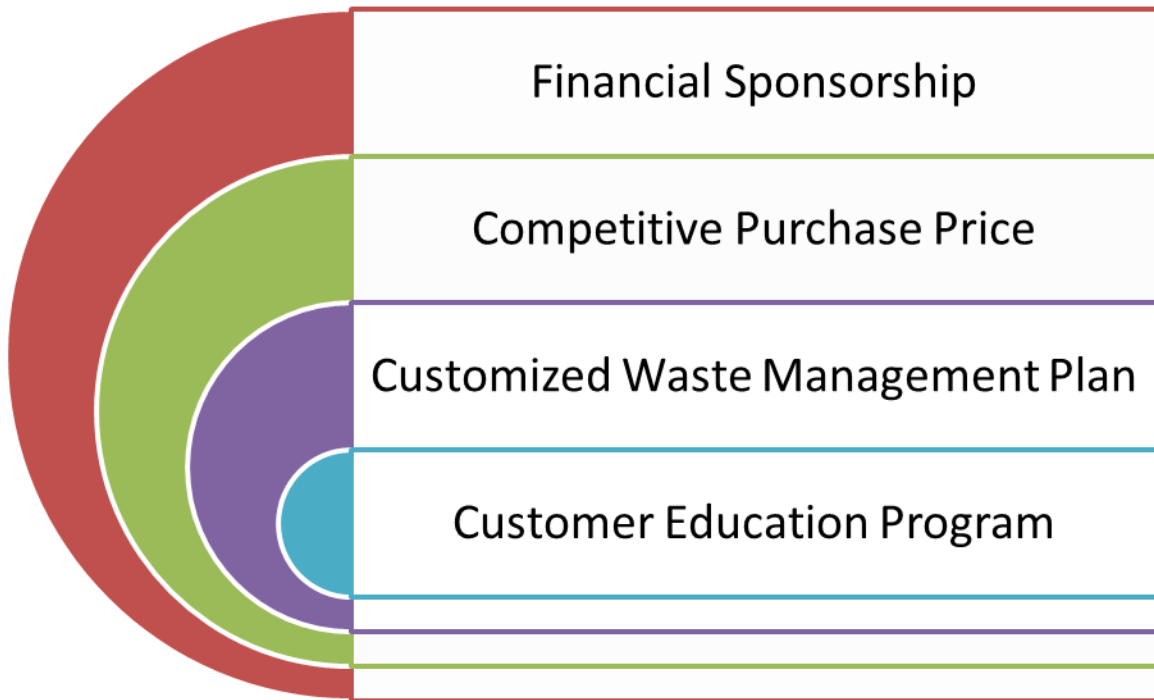
DUH has expressed a strong interest in switching to more sustainable tableware. However, sustainable containers, such as those from Eco Products, are estimated to cost about 20% more than the traditional containers currently in use.<sup>12</sup> With such a wide gap in price, the hospital is reluctant to increase food prices to compensate for the higher cost of sustainable containers. However, the hospital has made the switch to a cost-neutral, compostable substitute for one of its disposable plates that is made from sugarcane fiber, a byproduct of the sugar refining process.

One approach to overcoming the high costs would be to collaborate with DCOI to close the 20% price gap; another option would be to work with waste management companies on competitive contract prices and customized waste disposal plans. The current end-life options for sustainable tableware are: composting, feedstock recycling, recovery sorting, incineration with energy recovery, and landfilling.<sup>57</sup> Each type of anaerobic digester has its own technical capabilities and some may be able to accept post-consumer sustainable tableware along with organic waste. The combination of organic waste and sustainable tableware may produce a sufficient quantity of anaerobically digestible material to attract qualified waste management companies.

Based on a survey distributed by DUH, approximately 15% of the hospital's customers are interested in sustainable food containers; however, they are not willing to pay more.<sup>12</sup> This

relatively low percentage of interested customers shows that education programs could be implemented to increase awareness and commitment throughout the DUHS. It might help to educate the customers about the environmental benefits of sustainable tableware, such as the reduction of landfill waste, the decreased use of traditional wood fiber-based materials, and the reduced carbon footprint.<sup>8</sup> (See Figure 15)

**Figure 15: Sustainable Tableware Application Plan**



### Results and Discussion

According to the LCA analysis of styrofoam, PLA, and recycled paper, there would be an overall energy savings of 47% and a carbon emission reduction of 48% by switching from styrofoam to PLA. Switching from styrofoam to recycled paper products would increase the percentages to 89% and 41%, respectively. After calculating the carbon emissions from energy consumption, we found that switching to PLA products would reduce the carbon footprint by 47% and switching to recycled paper products would reduce it by 84% (see Table 4). The annual carbon reduction is estimated to be 406.23 to 723.81 tCO<sub>2</sub>e.

Financial analysis of the required incentives shows the same trend, which is 149.89\$/tCO<sub>2</sub>e for PLA and 83.57\$/tCO<sub>2</sub>e for recycled paper products (see Figure 16). However, the final decision must also take into account the relative prices of the available options, as well as the preferences of the contracted waste disposal company. The specific technology each company uses could result in different carbon emission rates of PLA and recycled paper products. In the long term,

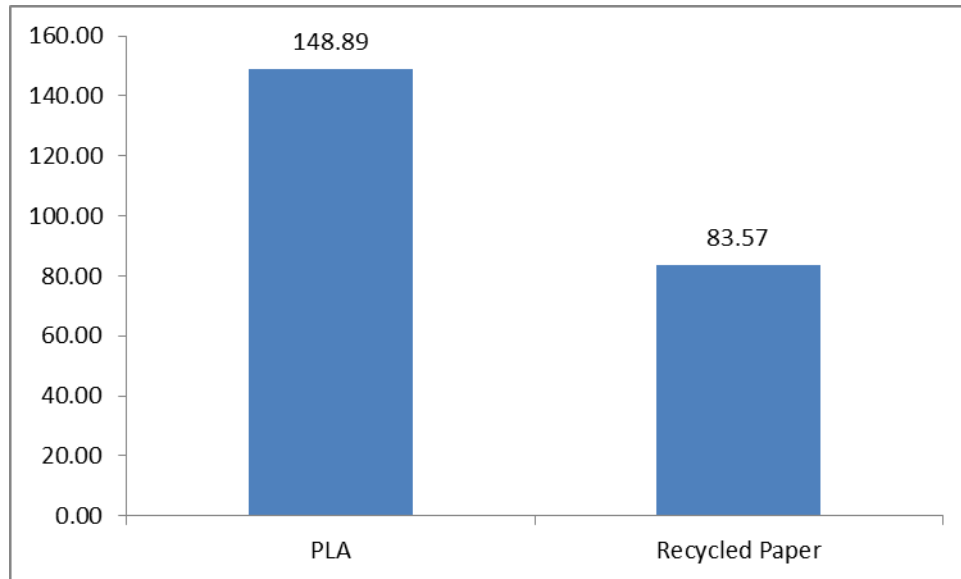
as crude oil prices continue to increase, sustainable tableware could eventually become less expensive than traditional plastic or styrofoam products.

Appendix C has the detailed calculations of the results below.

**Table 4: LCA Analysis --Carbon Emission Comparison**

	Baseline	PLA	Recycled Paper
<b>Daily energy consumption (KWh)</b>	2673.80	1415.69	289.88
<b>Daily carbon emission from energy (lbs)</b>	4682.79	2479.39	507.68
<b>Daily carbon emission (lbs)</b>	561.99	292.13	330.33
<b>Annual carbon emission (ton)</b>	861.46	455.22	137.64
<b>Annual net carbon reduction (ton)</b>	—	406.23	723.81

**Figure 16: Required Incentive from DCOI (\$/tCO<sub>2</sub>e)**



#### 4. Energy Efficient Kitchen Equipment

The kitchen renovations at DUHS involve replacing and supplementing the existing kitchen equipment. The models had been chosen based on need and balancing cost and benefit. Our team saw an opportunity to find equipment that was even more energy efficient than the models that had been chosen, given the potential for additional funding from DCOI. Based on initial research and advice from the kitchen renovation team, we focused on equipment with the largest energy demands, such as refrigerators, walk-in cold rooms, dishwashers, ovens, and ice machines. We examined options offered by large kitchen equipment manufacturers, kitchen manufacturers that were listed on the DOE webpage for Energy Star resources, and the

companies that DUHS had worked with in the past or had chosen to buy their equipment from this time.

For each type of equipment, we evaluated the key characteristics, such as electricity or natural gas use, water use, and cost. Throughout our evaluation, we kept in mind the functional and capacity requirements, as well as the pre-determined space footprint allocated to each piece of equipment. We presented the kitchen renovation team with 3 to 5 recommendations for each piece of equipment, providing advantages and disadvantages, as well as our best estimate of price.

In mid-March, the kitchen renovation team discovered that the rotary rack oven that they had initially selected was no longer being made; they instead will use one of the options that we had recommended. The new model is 12.5% more efficient than the initial choice and, estimating 8 hours use per day, will save 3.8 tons of CO<sub>2</sub> per year. Because this switch was financially attractive to DUHS without outside monetary assistance, DCOI did not fund this decision and will not acquire the associated carbon credits. The renovation lead will further examine our list of recommendations to determine if additional actions are warranted.

## **VIII. Conclusion and Recommendations**

The opportunities presented above could help DUHS reduce its carbon footprint now and in future renovations, while still keeping patient-care as its first priority. In subsidizing these projects, DCOI can continue to explore further opportunities to support environmentally sustainable initiatives at DUHS while obtaining the carbon credits necessary to fulfill the University's carbon neutrality goal by 2024.

### ***Lighting Upgrade***

Replacing T12 lamps with LED lights is both economically and environmentally feasible, considering the payback periods and NPVs. In addition, the required incentive is within DCOI's desired carbon offset price range (see Table 5). Our analysis shows that LED lighting is the preferable option when renovating the kitchen and when retrofitting existing fixtures. Furthermore, our model can be applied to other buildings in DUHS and the University.

### ***Organic Waste Disposal***

Alternative organic waste disposal methods are viable; however, the current required incentives are outside of DCOI's preferred price range. As the industries of composting and anaerobic digestion continue to develop, the disposal costs and associated required incentives are likely to decrease. Therefore, we encourage DUHS to take a leadership role in promoting the expansion

of these options and we recommend re-considering these approaches at a later date. Once the required incentives drop to an appropriate level, a contract with a third party waste management company is recommended. A local disposal company would be ideal, both to reduce the emissions from transportation and to strengthen ties within the community.

***Sustainable Tableware***

Implementing sustainable tableware would have the single largest effect on reducing carbon emissions and creating carbon credits. However, the required incentives are far beyond DCOI’s desired carbon offset range (see Table 5). Potentially, an advantageous bulk price may be negotiated between DUHS and the supplier. The final decision should consider not only the relative prices of available options but also the preference of the contracted waste management company, as their processes may be more applicable to certain types of sustainable tableware. Furthermore, anaerobic digestion for PLA products may become feasible at some point in the future.

**Table 5: Carbon Offset Opportunity Summary**

Category		Carbon Reduction (tCO <sub>2</sub> e/y)	Required Incentive (\$/tCO <sub>2</sub> e)
<b>Organic Waste Disposal</b>	Composting	21	150
	Anaerobic Digestion	2	59
<b>Sustainable Tableware</b>	PLA	406.24	148.89
	Recycled Paper	723.82	83.57
<b>Lighting</b>	Kitchen	102*	11
	Further Adoption	80-225/building*	4-6**

\*Total (not annual)

\*\*Or free (and not qualifying for carbon offsets) depending on DUH's arrangement with DCOI

***Culture of Sustainability***

Public awareness plays a vital role in environmental protection. The DUHS has already implemented numerous sustainable initiatives; we recommend that the DUHS take greater steps to inform their staff, clients, and the public about their good work. This outreach effort could increase worker satisfaction, enhance reputation within the community, and increase forward momentum to continue being a leader in sustainability.

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# Appendices

## Appendix A: Lighting Model

**Lifetime:** In figuring the relative lifetime costs of fluorescent linear lamps, a key variable is the lifetime of the lamp. The lifetime of a lamp, known as the average rated life, is the number of hours at which half of the lamps have failed, at an operating cycle of 3 hours on and 20 minutes off, as defined by the Illuminated Engineering Society of North America (IESNA).<sup>43</sup> However, a number of factors can significantly impact the lifetime. The operating cycle (how often the light is turned on and off) greatly impacts the lifetime; each cycle decreases the lifetime of the lamp.<sup>43</sup> Therefore, if the actual operating cycle of the lamp will be 12 hours on, 12 hours off (as may be found in an industrial facility), the lifetime of the lamp may be greater than the average rated life, as defined by the IESNA. Furthermore, the type of ballast chosen will affect the lifetime: rapid-start ballasts allow for longer lifetimes than instant-start ballasts.<sup>43</sup> In addition, a single number such as average rated life does not encompass all the information. Lamp failure rate, provided by the standard deviation of the average rated life, can impact the usefulness of a group of lamps.<sup>43</sup> For example, if a facility's policy is to replace all the lamps in a room once 2 of the lamps have ceased to function, the lifetime variability of the lamps is a highly important factor. For this lighting model, the advertised lifetimes of lamps and ballasts were taken at face value and then compared to DOE studies for corroboration.

**Labor:** The man-hours needed to install and replace lighting devices were estimated by the assistant director of engineering and operations. The cost of labor reflects the total cost of an employee, including insurance and other background costs.

**Materials cost:** Because buying in bulk often confers a price reduction, but also necessitates obtaining a quote, the device prices for the lighting model were estimated. Retail prices were found on-line and then adjusted to reflect a 10% discount for buying in bulk.<sup>51</sup> In general, replacement fixtures were found to be roughly three times as expensive as the corresponding retrofit kits. Both options often include lamps and ballast or transformer.

**Carbon intensity of electricity:** The most recent data from the EPA (eGrid2010) indicates that the 2007 emissions intensity of electricity produced in the EPA subregion 'SERC Carolina-Virginia' is 0.6846 tons CO<sub>2</sub>e/MWh.<sup>31</sup> This value can be applied to energy use by lighting and appliances to determine annual emissions. In addition, this value is consistent with data from Duke Energy. Using environmental performance metrics data from Duke Energy's website,<sup>29</sup> the carbon emissions from an average MWh can be calculated: (97,600,000 tons CO<sub>2</sub>) / (148,642,000 MWh), for US production in 2010, gives 0.6566 ton CO<sub>2</sub> per MWh.

**Electricity use:** The electricity used by lamps and ballasts has been measured in laboratory settings.<sup>43</sup>

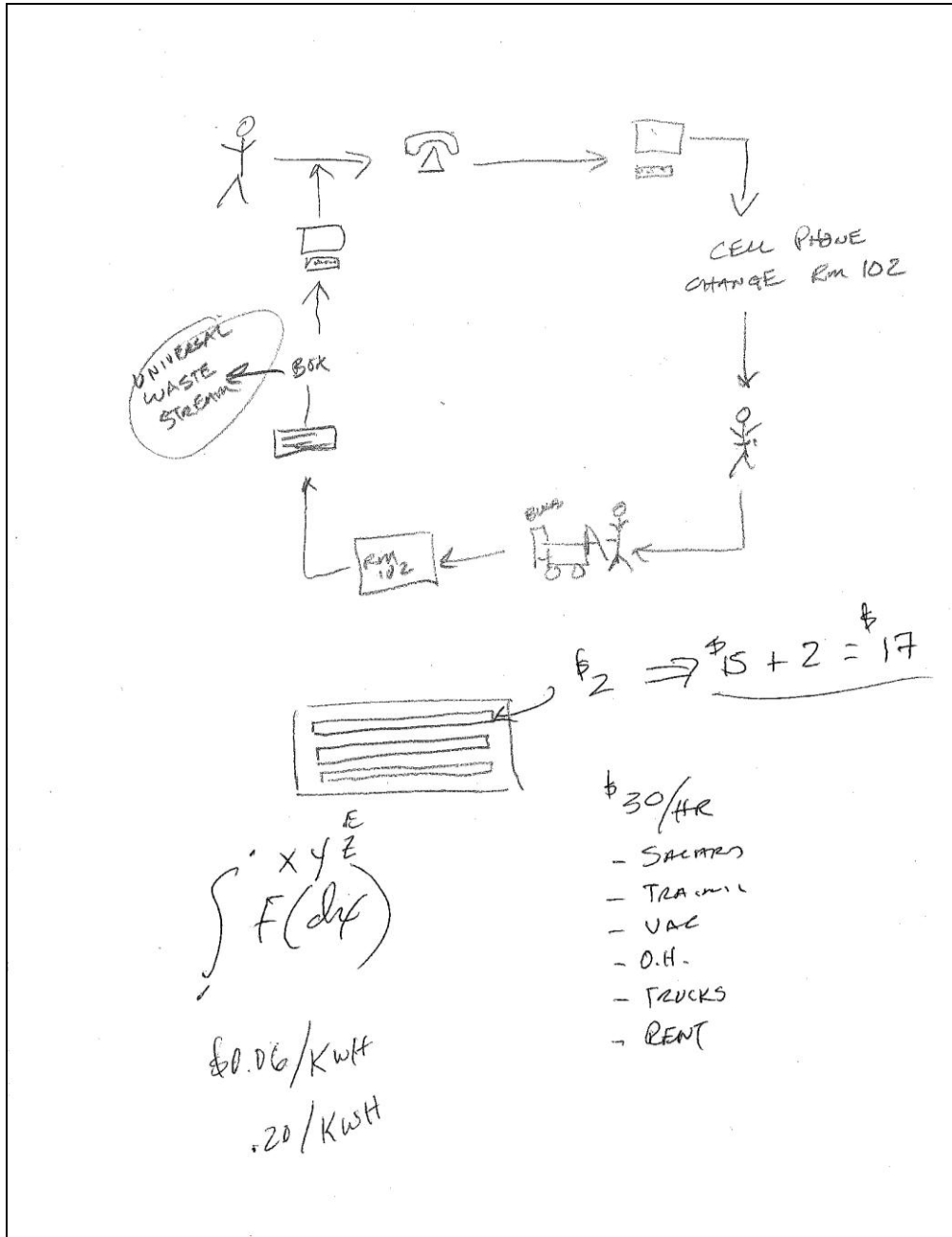
**Lifecycle carbon:** The lifecycle carbon emissions of lighting devices come primarily from the use phase.<sup>39,41</sup> Emissions from the manufacturing and transportation phases are difficult to quantify and to find in the literature. This model includes only the emissions from the use phase, encompassing 80% of the lifecycle carbon emissions of the lamps.<sup>39</sup> Because this method was applied uniformly across the different types of lamps, the carbon emissions of the lamps can be compared.

**Cost of electricity:** DUH buys electricity from Duke Energy at a commercial rate. This rate is expected to increase over time. In this model, the cost of electricity was kept constant at the fiscal year 2013 prices. Higher costs of electricity tend to make more energy efficient lighting choices more financially attractive; thus, setting the electricity rate at its minimum provides conservative results.

**Discount factor:** The discount factor is closely related to the hurdle rate. The hurdle rate represents the required rate of return on projects and investments. The hurdle rate at DUHS ranges from 9-12%, based on the type of project; 10% was used in the lighting model.<sup>20</sup> The hurdle rate is used in the calculation of net present value and in the evaluation of the project's internal rate of return (IRR). If a project has an IRR lower than the hurdle rate, then, on a purely financial basis, the project is not recommended. (However, the project may still be implemented based on other factors.) The model is able to account for a range of discount factors. Because LED lamps and fluorescent lamps require capital and maintenance at different times, the choice of discount factor has a large impact on the model results.

**Payback period:** The payback period required for DUH to make investments may be dependent on the type of investment and on other factors. Therefore, results were provided for a variety of payback periods.

**Rough sketch of replacement process and labor cost of light bulbs  
by Robert Guerry, Director of Engineering, DUHS**



## Appendix B: Organic Waste Carbon Reduction Calculation

Food waste generation estimation	Lbs	Tons	Source
Daily	230	0.12	ARAMARK waste tracking tool (03/18/2012-03/27/2012) *Consumer leftovers excluded
Annually	83950	41.98	Calculated from daily data

Net carbon reduction factor	Data (tCO <sub>2</sub> e/ton)	Source
Composting	0.05	<a href="http://www.dec.ny.gov/chemical/8798.html">http://www.dec.ny.gov/chemical/8798.html</a> Department of Environmental Conservation, New York
Anaerobic digestion	0.75	<a href="http://www.biogen.co.uk/over-about-ad.asp">http://www.biogen.co.uk/over-about-ad.asp</a> . *The lower end of the range, 0.5-1, was used as a conservative estimate

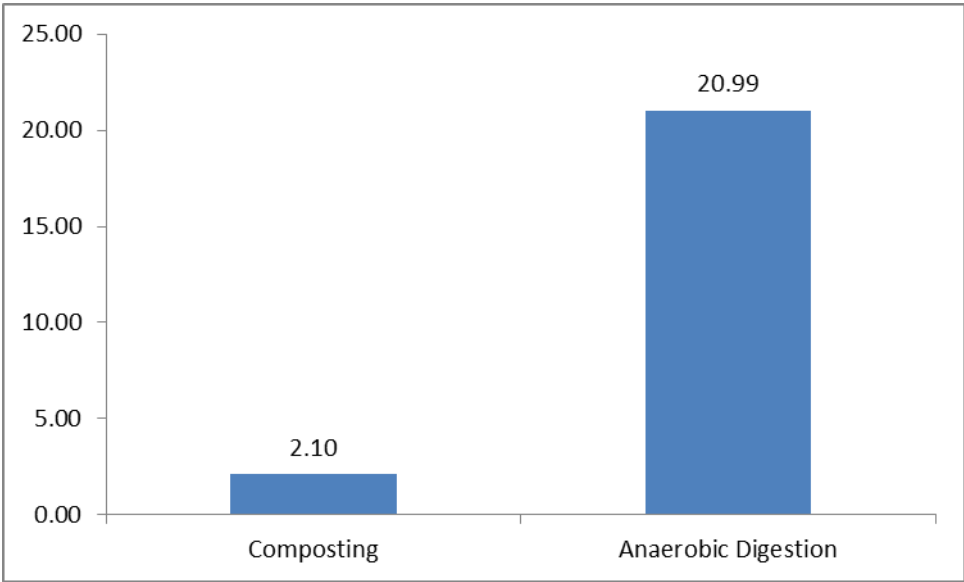
Carbon emission factor	tCO <sub>2</sub> e /ton	Source
Landfill	0.69	<a href="http://epa.gov/climatechange/wycd/waste/downloads/Organics.pdf">http://epa.gov/climatechange/wycd/waste/downloads/Organics.pdf</a>
Composting	0.64	Calculated from net carbon reduction factor
Anaerobic digestion	0.19	Calculated from net carbon reduction factor

Carbon generation estimation (tons)	Landfill	Composting	Anaerobic digestion
Annually	28.96	26.86	7.98

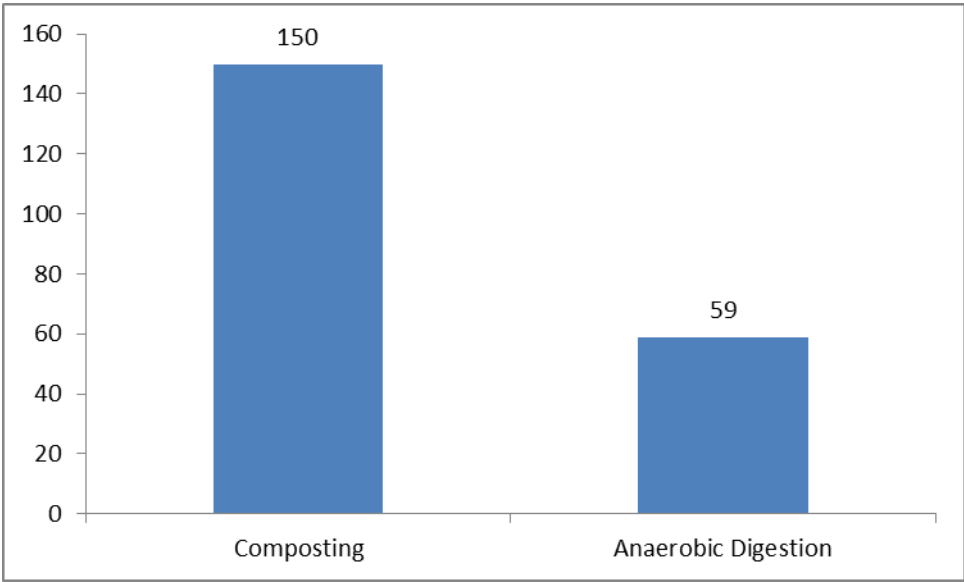
Net carbon reduction estimation (tons)	Composting	Anaerobic digestion
Annually	2.10	20.99

Organic waste recycling cost analysis	\$/ton	Required incentive (\$/tCO <sub>2</sub> e)
Landfill	42.5 <sup>13</sup>	—
Composting	50.00 <sup>61</sup>	1000.00
Anaerobic digestion	72.00 <sup>61</sup>	44.00

**Organic Waste Carbon Reduction Potential (tCO<sub>2</sub>e/y)**



**Required Incentive from DCOI (\$/tCO<sub>2</sub>e)**



## **Organic Waste Management Company Profiles in the Durham Area:**

Full Circle Recycle NC: Formerly Barham Farm, Full Circle has a 750,000 gallon anaerobic digester which treats almost all kinds of organic waste on a large scale.<sup>70</sup> The methane and biofuel produced on-site is used to produce energy to heat the greenhouse for the farm's cucumber production and keep it warm year-round.<sup>69</sup> Full Circle typically charges \$20/ton in tipping fees.<sup>75</sup>

Stanley Environmental Solutions Inc.: owned by Jin Lanier, Tommy Morrison and Eric Lutz. Their service area covers North and South Carolina.<sup>46</sup> Stanley recently invested in a third dewatering box in Durham, located 60 miles away. It is expected to process about 40,000 gallons per day within a year.<sup>88</sup>

Waste Management: As one of the largest recycling companies in the US, Waste Management provides necessary infrastructure for commercial organic waste recycling, including specifically designed containers and trucks, as well as training and support. Organic waste materials will be transported to a special facility where it will be turned into compost, soil amendments, and energy.<sup>59</sup> In addition, Waste Management has invested in Harvest Power so that it can expand its organic waste recycling processing facilities across North America and develop a waste-to-energy industry through innovative anaerobic digestion technology. It also invested in Terrabon to produce renewable transportation fuels from organic waste via a unique technology called MixAlco™ in 2009.<sup>62</sup>

## Appendix C: Sustainable Tableware LCA Analysis

### Carbon Intensity of Electricity in Asian Countries<sup>10</sup>

Country	Electricity generated	CO <sub>2</sub> emissions	Energy mix			Carbon intensity	Weighted %	Weighted average carbon intensity (kg CO <sub>2</sub> /MWh)
	TWh	million tons	fossil	hydro	nuclear	kg CO <sub>2</sub> /MWh		
China	3260	2830	0.83	0.15	0.02	868	0.6609	794.408
India	719	579	0.76	0.16	0.02	805	0.1458	
Indonesia	125	83	0.78	0.09	0	662	0.0253	
Malaysia	95	59	0.86	0.06	0	626	0.0193	
Taiwan (China)	218	124	0.59	0.04	0.17	570	0.0442	
Thailand	124	70	0.92	0.05	0	563	0.0251	
South Korea	392	174	0.44	0.01	0.35	444	0.0795	

Average carbon emission intensity in the Asian electricity industry	Unit
794.408	kg CO <sub>2</sub> /MWh
1.75136	lbs/KWh

### LCA Data<sup>11</sup>

Manufacturing one pound of the final product	Energy (KWh/lb)	CO <sub>2</sub> emissions (lbs)
EPS thermoforming (expandable polystyrene / styrofoam - plastic)	11.95	2.51
100% recycled paperboard	3.14	1.47
PLA (polylactic acid - injection molding)	6.3	1.3 <sup>47</sup>
PVC (polyvinyl chloride- plastic)	7.95	1.8 <sup>67</sup>



## Environmental Impact Analysis

Type	Material	Daily consumption	Weight (lb/product)	Energy consumption (KWh)			Carbon emissions (lbs)		
				Baseline	PLA scenario	Recycled paper scenario	Baseline	PLA scenario	Recycled paper scenario
To-go-box 9in 1 compartments	Styrofoam	3600	0.04	1763.82	929.88	227.07	370.48	191.88	216.97
To-go-box 6in 1 compartments	Styrofoam	1600	0.03	522.61	275.52	44.85	109.77	56.85	64.29
Pleats 9in	Styrofoam	800	0.02	189.29	99.79	11.77	39.76	20.59	23.28
Pleats 6in	Styrofoam	250	0.01	39.44	20.79	1.63	8.28	4.29	4.85
Salad to-go-box	Styrofoam	80	N/A	0.00	0.00	0.00	0.00	0.00	0.00
Drink cup (all sizes)	Styrofoam	800	0.01	95.60	50.40	3.00	20.08	10.40	11.76
Soup cup (all sizes)	Styrofoam	300	0.01	40.15	21.17	1.41	8.43	4.37	4.94
Drink cup lids (all sizes)	#3 plastic	800	0.00	12.72	10.08	0.08	2.88	2.08	2.35
Straws	#3 plastic	800	0.00	10.18	8.06	0.05	2.30	1.66	1.88

\*Tableware consumption data from Cy Gropper, Retail Director, ARAMARK Healthcare

Category	Baseline	PLA	Recycled paper
Daily energy consumption (KWh)	2673.80	1415.69	289.88
Daily carbon emissions from energy (lbs)	4682.79	2479.39	507.68
Daily carbon emissions (lbs)	561.99	292.13	330.33
Annual carbon emissions (tons)	861.46	455.22	137.64
Annual Net Carbon Reductions (tons)	---	406.23	723.81

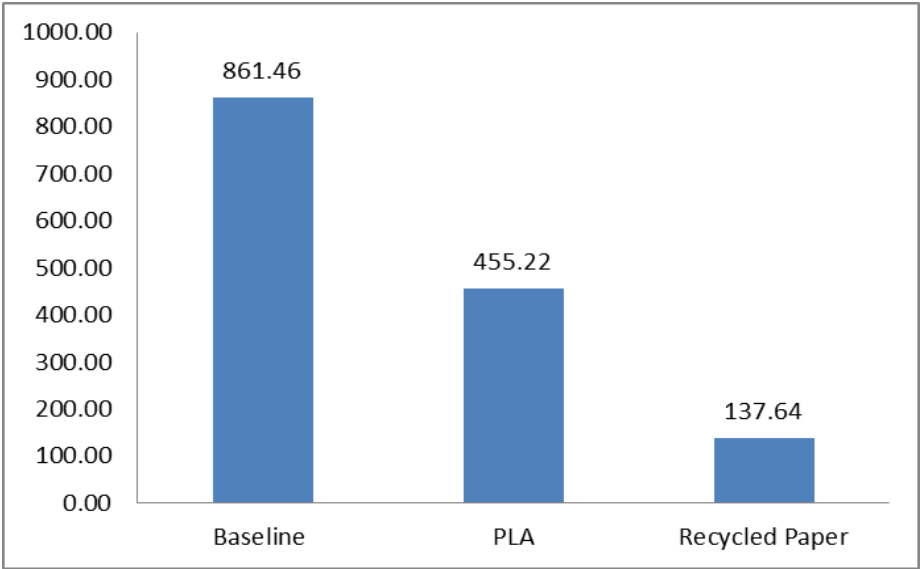
## Financial Analysis

Category	Purchase cost (\$)	Source
Disposable tableware	Weekly	5800
	Annually	302428.57
Sustainable tableware	Annually	362914.29

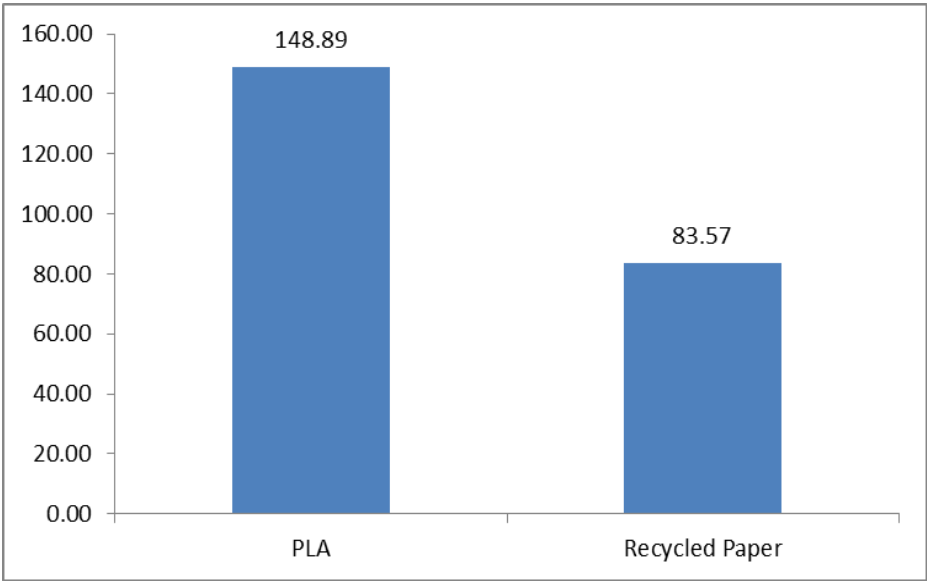
Jeff Saunders, Purchasing Manager, Food Services, DUHS (email, March 29, 2012)  
 Calculated from weekly data  
 Assumed 20% financial gap (meeting with Ed Chan, Jan 26, 2012)

Alternative options	Required incentive (\$/tCO <sub>2</sub> e)
PLA	148.89
Recycled paper	83.57

**Estimation of Annual Carbon Emissions from LCA Analysis (tCO<sub>2</sub>e)**



**Required Incentives from DCOI (\$/tCO<sub>2</sub>e):**



## Appendix D: Glossary of Terms

*Additionality*: the criteria that the emissions reductions would not have occurred, holding all else constant, if the activity were not implemented as an offset project.<sup>48</sup>

*Carbon offset*: the reduction, removal, or avoidance of GHG emissions from a specific project that is used to compensate for GHG emissions occurring elsewhere.”<sup>72</sup>

*Organic waste*: anything that comes from plants or animals that is biodegradable.<sup>58</sup>

*Anaerobic digestion*: a complex biological process that takes place in the absence of oxygen. Facilitation of anaerobic digestion involves a large, sealed, and insulated vessel, controlled temperatures, and bacteria supplementation. During this process, biogas (methane) is produced and generally captured in tanks for future use.

*Composting*: an accelerated process of decomposition that returns the organic material to soil or other valuable products.

*Lighting efficiency*: lumens/watt

*Light emitting diode (LED)*: small sources of light that become illuminated when electrons move through a semiconductor material.<sup>76</sup>

*Levelized cost of energy*: the average dollar cost of energy from a given generating source, taking into account capital costs, operations and maintenance, performance, and fuel costs.<sup>52</sup>

*Life cycle assessment*: a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave (i.e. from raw material extraction to materials processing, manufacture, distribution, use, repair, maintenance, and disposal or recycling).<sup>15</sup>

*T12, T8, and T5 lamps*: fluorescent tubular lamps used in commercial and industrial settings. The number after ‘T’ refers to the diameter of the lamp, in eighths of an inch.

*Lamp*: the technical term for a light bulb