I, Carol Clinton, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Environmental Engineering.

It is entitled:
Transformation of a University Climate Action Plan into a Sustainability Plan and Creation of an Implementation Prioritization Tool

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DOCTORAL DISSERTATION:

Transformation of a University Climate Action Plan

into a Sustainability Plan

and Creation of an Implementation Prioritization Tool

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Abstract

Sustainability is a concept that recognizes the interconnectedness and necessary balance of economic, environmental, and social issues. The most widely accepted articulation is from the United Nations Brundtland Commission (United Nations, 1987):

"Sustainable development ... meets the needs of the present without compromising the ability of future generations to meet their own needs".

One aspect of sustainability is the “carbon footprint,” which reflects emissions of six greenhouse gases (GHG) in terms of carbon dioxide equivalents on the basis of their global warming potential. The carbon footprint for the University of Cincinnati (UC) had previously been computed and an action plan had been defined, listing potential mitigations to reduce GHG emissions.

However, GHG emissions comprise only a portion of the scope of sustainability issues faced at UC. A comprehensive sustainability model was created during this study in order to give a more holistic framework for university decision-making around resource allocation by including Brundtland-style impacts on a) economy; b) environment—particularly, water use; and c) social equity.

To create the new framework, more than 600 indicators from key sustainability metric systems were analyzed. Systems included the Global Reporting Initiative, United Nations (UN) Millennium Development Goals, UN Commission on Sustainable Development indicators, and USEPA Report on the Environment indicators, plus systems relating specifically to universities: the Association for the Advancement of Sustainability in Higher Education Sustainability Tracking, Assessment & Rating System; the Princeton Review Green Campus criteria; the Sustainable Endowments Institution College Sustainability Green Report Card; and the UC 2019 Strategic Plan, which includes sustainability as an
institutional goal. None of the existing sustainability sets covered all the elements relevant to UC. A new comprehensive set of indicators was defined to gauge UC performance across the three sustainability categories of economy, environment and social equity.

Based on the new sustainability framework, over 300 potential mitigation actions were identified to improve UC sustainability performance. Their costs and benefits were compared to a list of 107 possible GHG reduction actions that had been listed in the UC Climate Action Plan (CAP). To perform this analysis, several factors customized to UC were computed, including an estimate of energy embedded in drinking water from the Greater Cincinnati Water Works, and factors for GHG emitted per unit of individual utilities used at UC. A new suite of optimally effective actions was defined that maximizes results per dollar spent. Sustainability consideration resulted in actions being deployed in different buildings than those listed in the CAP. The set of sustainability actions had a higher Net Present Value, shorter payback period, and resulted in more GHG emission reductions.

While the resulting prioritized action set applies specifically to UC operations, the sustainability framework and the action prioritization methodology could be applied to other universities and organizations in virtually any sector interested in improving their sustainability performance by defining those actions that have maximal impact on sustainability.

Several areas of opportunity were also identified for future research in order to further understand sustainability and advance performance in that field
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Acknowledgements

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I’m also grateful for the patient and wise guidance of my co-advisors Dr. Paul Bishop and Dr. Margaret Kupferle, the inspiration from committee members, the support of friends and family, and the Source of it all, my Lord Jesus the Christ.

I’ve been truly blessed to have the opportunity to study and play in this field of sustainability that ties together so many of the stray threads of my life. I look forward to applying its principles towards continual improvement of other organizations as I once again leave this “fountain of eternal youth”.

Thanks to all who have shared this adventure with me!
Table of Contents

*Front Matter*

Title Page.........................................................................................................................................i
Abstract.............................................................................................................................................ii
Copyright Notice...........................................................................................................................iv
Acknowledgements......................................................................................................................v
Table of Contents........................................................................................................................vi

*Body Text*

1.0 INTRODUCTION .........................................................................................................................1
  1.1 Overview...................................................................................................................................1
  1.2 Unique Contribution ...............................................................................................................2

2.0 STATEMENT OF THE PROBLEM ..............................................................................................2

3.0 HYPOTHESIS ................................................................................................................................3

4.0 RESEARCH OBJECTIVES AND RESULTS ..............................................................................4
  4.1 OBJECTIVE 1: Refine Carbon Footprint Assessment .............................................................4
    4.1.1 Previous Carbon Footprint Analysis ...................................................................................4
    4.1.2. Modeling Process Overview ............................................................................................9
    4.1.3 Definition of Boundaries ....................................................................................................11
    4.1.4. GHG Protocol Compliance ...............................................................................................12
    4.1.5 Methodology for Updating Previously “Low Comfort Level” Transportation Inputs........14
    4.1.6 Discussion of GHG Modeling Results ...............................................................................16
    4.1.7 Recommendations for Future Carbon Footprint Modeling Work ..................................22
  4.2 OBJECTIVE 2: Creation of Comprehensive Sustainability Framework ................................23
    4.2.1 Overview ............................................................................................................................23
    4.2.2 Discussion of Sustainability Systems ...............................................................................24
Tables and Figures

Tables

Table 1. Summary of UC Carbon Footprint Modeling Results by Scope..................................................... 6
Table 2. Details of UC Carbon Footprint Modeling Results by Emission Category ........................................... 7
Table 3. Comparison of Energy Emissions Normalized Per Square Footage of Total Campus Buildings 21
Table 4. Comparison of Indicator Systems Assessed …………………………………………………………… 29
Table 5. UC GHG Mitigation Options – Summarized by Project Type .......................................................... 33
Table 6. UC GHG Mitigation Options – Summarized by Building.................................................................. 34
Table 7. Dorm Utility Consumption Normalized by Resident .......................................................................... 38
Table 8. Comparison of Targeted Buildings for Energy Reduction Actions .................................................. 50
Table 9. Comparison of Targeted Buildings for Water Reduction Actions ................................................... 51
Table 10. Water Fixture Flow Rates .............................................................................................................. 52
Table 11. Summary Comparison of Water Savings Actions .......................................................................... 53

Figures

Figure 1. Overview of Project Goals. ............................................................................................................. 1
Figure 2. Overview of UC GHG scopes and emission categories ................................................................. 5
Figure 3. Relative Contributions of UC GHG Emission Sources, 2008 vs. 2010 Modeling ............................. 8
Figure 4. Detailed Comparison of Relative Contributions of Types of GHG Emissions and Details of

   Energy and Transportation Impacts, 2007–2010 ................................................................................. 17
Appendices

A: Inputs for Updated Carbon Footprint Analysis
B: Comparative Results of Carbon Footprint Analyses 2007–2010
C: Comparison and Definition of UC Sustainability Framework
D: Energy Consumption by UC Main Campus Buildings (from UC 2009 Climate Action Plan)
E: Climate Action Plan Measures (GHG Only)
F: UC Building Utility Use Summary
G: Example Aerial Photos of East & West Campus for Identifying Roof Options
H: UC Electricity Emission Factors
I: Sustainability Action Plan
J: Extra Sustainability Actions
K: Comparison of Potential Water Saving Actions
L: Optimization Modeling Results
M: Additional Data Needs
1.0 INTRODUCTION

1.1 Overview

This doctoral research work, depicted in Figure 1, transformed the existing University of Cincinnati (UC) Uptown Campus Climate Action Plan into a Sustainability Action Plan by adding mechanisms for considering more holistic, Brundtland-style impacts on a) economy, b) environment—particularly water use, and c) social equity. A model was also created to prioritize actions for effective implementation of the plan. This resulted in a comprehensive framework for defining, measuring, and managing sustainability performance.

Figure 1. Overview of Project Goals.
The color coding shown in Figure 1 (economy = green, environment = blue, and social = pink) will be continued throughout this document.

1.2 Unique Contribution

This study applied an environmental engineering systems approach in order to define customized metrics and then analyze them through a new optimization model to define those that have maximal impact on sustainability. Using these new metrics to develop a useful model for guiding decision-making will help prevent misallocation of human, financial, and material resources.

2.0 STATEMENT OF THE PROBLEM

The pre-existing UC Climate Action Plan (UC, 2009) was prepared from a baseline assessment using the Clean Air-Cool Planet (CA-CP) carbon footprint calculator (Clean Air-Cool Planet, 2007) and data from fiscal years 2004 through 2008. The calculator computes emissions of six regulated greenhouse gases (GHG)—carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—in terms of CO₂ equivalents on the basis of each gas’ global warming potential (GWP). All the factors and equations are built into the model, which requires more than 170 data inputs. These inputs include institutional data, raw materials for on-campus energy generation, energy, GHG refrigerant purchases, and additional items. CA-CP results showed emissions in four categories: energy, transportation, solid waste, and refrigerants and other chemicals. Several data inputs to the baseline analysis, predominantly in the transportation category that accounted for roughly 20% of the resulting UC carbon footprint, were considered to be “low comfort level” quality (UC, 2009). New techniques were needed to develop more accurate data inputs for these elements in a required 2010 updated footprint assessment which was completed as part of this project.
However, the CA-CP model does not address all sources of GHG emissions. For example, water use, which embodies an unaccounted for carbon footprint due to energy required to produce and distribute it, is an important indicator of sustainability in its own right, but is missing from the CA-CP model. In fact, the existing model is silent on all economic and social aspects of sustainability as defined by the Brundtland Commission (UN, 1987). A university such as UC is similar to a small city (UC, 2009, p. 1–5) in scope of services provided, such as housing, food, and transportation; its economic impact as one of the largest employers in Cincinnati; and its unique social impact through its educational and research mission. Obviously, many sustainability aspects applicable to UC are missing in the current analysis.

Finally, in the Climate Action Plan which was based on the initial carbon footprint, hundreds of separate mitigation strategies were suggested for many university functions. For example, in the transportation section alone, fifty-five ideas were listed, but no costs or quantitative benefits were presented. One appendix included details on building energy use reduction opportunities and presented estimates of costs and benefits. The Plan also included projections for GHG reductions based on blanket assumptions about achieving percentage reduction targets for some of the footprint outputs (e.g., 2–3 % reduction in CO₂ per year for the next 10–15 years) (UC, 2009, p.3–20). However, there was no specific implementation plan or prioritization for the mitigation actions that linked them to the expected reductions. To implement a plan, specific priorities must be assigned and decisions made about how to best allocate resources. This had not formally been done for the UC Climate Action Plan.

3.0 HYPOTHESIS

Current systems for computing carbon footprint and creating climate action plans consider only a narrow subset of sustainability, and as a result, fail to capture the full potential of the action planning process and
miss potentially important elements of the carbon footprint. For organizations aspiring to “sustainability,”
there are core subsets of activities that yield superior performance.

To study this hypothesis, a project was defined and executed. The project had three core elements:

1. Refining the UC carbon footprint assessment,
2. Creating a comprehensive sustainability framework, and
3. Developing a decision-making model to prioritize potential improvement actions.

4.0 RESEARCH OBJECTIVES AND RESULTS

4.1 OBJECTIVE 1: Refine Carbon Footprint Assessment

4.1.1 Previous Carbon Footprint Analysis

The University’s participation in the American College & University Presidents’ Climate Commitment (ACUPCC) requires that inventories of GHG emissions be performed biennially (ACUPCC, 2009). ACUPCC allows use of any method that is consistent with standards of the GHG Protocol of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), but recommends the Clean Air – Cool Planet (CA-CP) Campus Carbon Calculator. The GHG Protocol (WRI/WBCSD, 2004) is based on the ISO 14064 Greenhouse Gas Emission Reporting Standards. These systems categorize GHG emission “scopes” according to source, as illustrated in Figure 2.
“Scope 1” are direct GHG emissions from sources owned or controlled by the reporter, “Scope 2” are GHG emissions from the generation of purchased electricity consumed by the reporting entity, and “Scope 3” are other indirect GHG emissions. ACUPCC requires universities to include Scope 3 emissions from student, faculty, and staff commuting and from institutionally funded air travel. They also encourage inclusion of Scope 3 emissions from purchased goods and services.

The initial UC survey (carbon footprint) was completed in 2008 using data for 2004 through 2007 from the Uptown Campus (East and West Campuses) with CA-CP model Version 5.0. Modeling was updated as part of this project using CA-CP Version 6.4 with data through 2010. Comparative results of original (2008) and updated (2010) modeling are summarized in Table 1 by scope, and Table 2 by emission category.
Table 1. Summary of UC Carbon Footprint Modeling Results by Scope

(Metric Tonnes CO₂ Equivalents)

<table>
<thead>
<tr>
<th>Reporting Year</th>
<th>Total Scope 1</th>
<th>Total Scope 2</th>
<th>Total Scope 3</th>
<th>Total Offsets</th>
<th>Net Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY 2008</td>
<td>111,936.1</td>
<td>191,477.9</td>
<td>68,895.4</td>
<td>-1,041.9</td>
<td>371,267</td>
</tr>
<tr>
<td>FY 2009</td>
<td>112,205.1</td>
<td>189,077.0</td>
<td>176,143.9</td>
<td>-254.9</td>
<td>477,171</td>
</tr>
<tr>
<td>FY 1010</td>
<td>193,360.6</td>
<td>87,445.3</td>
<td>174,720.6</td>
<td>-305.2</td>
<td>455,221</td>
</tr>
</tbody>
</table>
Table 2. Details of UC Carbon Footprint Modeling Results by Emission Category

(Metric Tonnes CO₂ Equivalents)

<table>
<thead>
<tr>
<th>Emission Category</th>
<th>Sub-category</th>
<th>2008</th>
<th>% of Total</th>
<th>2009</th>
<th>% of Total</th>
<th>2010</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GHG Emissions (MT CO₂e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Purchased electricity</td>
<td>191,478</td>
<td>51.4</td>
<td>189,077</td>
<td>39.6</td>
<td>87,445</td>
<td>19.2</td>
</tr>
<tr>
<td></td>
<td>Non co-gen (on-campus stationary)</td>
<td>94,171</td>
<td>25.3</td>
<td>103,267</td>
<td>21.6</td>
<td>112,172</td>
<td>24.6</td>
</tr>
<tr>
<td></td>
<td>Co-gen Electric (on-campus stationary)</td>
<td>15,761</td>
<td>4.2</td>
<td>3,869</td>
<td>0.8</td>
<td>34,195</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Co-gen Steam (on-campus stationary)</td>
<td>69</td>
<td>0.0</td>
<td>3,825</td>
<td>0.8</td>
<td>44,903</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>T&amp;D losses</td>
<td>*</td>
<td>*</td>
<td>18,700</td>
<td>3.9</td>
<td>8,648</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td><strong>Total Energy</strong></td>
<td>301,479</td>
<td>80.9</td>
<td>318,739</td>
<td>66.8</td>
<td>287,363</td>
<td>63.1</td>
</tr>
<tr>
<td>Transportation</td>
<td>Fleet</td>
<td>934</td>
<td>0.3</td>
<td>890</td>
<td>0.2</td>
<td>904</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Student commuters</td>
<td>53,352</td>
<td>14.3</td>
<td>33,363</td>
<td>7.0</td>
<td>36,561</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Faculty/staff commuters</td>
<td>12,729</td>
<td>3.4</td>
<td>13,488</td>
<td>2.8</td>
<td>14,757</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Air travel</td>
<td>2,279</td>
<td>0.6</td>
<td>94,122</td>
<td>20.0</td>
<td>97,780</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>Other directly financed travel</td>
<td>*</td>
<td>*</td>
<td>15,475</td>
<td>3.3</td>
<td>16,076</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td><strong>Total Transportation</strong></td>
<td>69,293</td>
<td>18.6</td>
<td>157,337</td>
<td>33.0</td>
<td>166,078</td>
<td>36.5</td>
</tr>
<tr>
<td>Solid Waste</td>
<td></td>
<td>536</td>
<td>0.1</td>
<td>512</td>
<td>0.1</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>Refrigerants and Other Chemicals</td>
<td>1,001</td>
<td>0.3</td>
<td>337</td>
<td>0.1</td>
<td>1,169</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>*</td>
<td>*</td>
<td>17</td>
<td>0.0</td>
<td>19</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Paper Purchases</td>
<td>*</td>
<td>*</td>
<td>485</td>
<td>0.1</td>
<td>386</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Wastewater</td>
<td>*</td>
<td>*</td>
<td>&lt;1</td>
<td>0.0</td>
<td>&lt;1</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total GHG Emissions (MT CO₂e)</strong></td>
<td>372,309</td>
<td>100</td>
<td>477,426</td>
<td>100</td>
<td>455,526</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Offsets</td>
<td>-1,042</td>
<td>-0.3</td>
<td>-255</td>
<td>-0.1</td>
<td>-305</td>
<td>-0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Net Emissions</strong></td>
<td><strong>371,268</strong></td>
<td><strong>477,171</strong></td>
<td><strong>455,221</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color coding</td>
<td>Scope 1 (direct)</td>
<td>Scope 2 (indirect from purchased electricity)</td>
<td>Scope 3 (other indirect)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3 illustrates relative contribution of emission sources, contrasting original and updated modeling results. In both modeling efforts, energy was the largest category of UC’s impact, accounting for 81% of the total in the original modeling and 63% in the update. Transportation was second with 18% originally and 37% in the update. Refrigerants and other chemicals accounted for 0.3%, and solid waste contributed 0.1% in both modeling exercises.

The CA-CP model includes GHG emissions from wastewater, principally due to methane from collection and treatment, but does not address the carbon footprint of supplied water. This “water-energy nexus” is receiving national attention, with the Electric Power Research Institute (EPRI, 2000) estimating that roughly 4 percent of U.S. electricity is consumed for pumping raw water, treating it, and pumping it through distribution systems. This Scope 3 emission was addressed in the Sustainability Action Plan phase of this study.

![Figure 3. Relative Contributions of UC GHG Emission Sources, 2008 vs. 2010 Modeling.](image-url)
The energy category for UC comprises a combination of Scope 1 direct emissions from combustion of coal, natural gas and fuel oil in boilers, chillers, and a cogeneration plant that generate steam, chilled water and electricity. Scope 2 indirect emissions from purchased electricity, and Scope 3 indirect emissions reflecting electricity transmission and distribution (T&D) losses are also in the energy category. The transportation category is a combination of Scope 1 direct emissions from UC vehicles and Scope 3 indirect emissions from commuting and other travel associated with university functions.

4.1.2. Modeling Process Overview

The University of Cincinnati (UC) was founded in 1819 and is a large, urban, research university with more than 41,000 students. Operations occur at four campuses and several satellite research facilities, all located within the Greater Cincinnati area in southwest Ohio. The main or “uptown” campus was the focus of this work, and includes the West (Main) and East (Medical) Campus. Together, these campuses are home to 15 of the university’s 17 colleges, several hospitals, and related facilities.

UC joined the American College and University President’s Climate Commitment (ACUPCC) in 2007, completed its first GHG inventory in 2008, and defined a Climate Action Plan in 2009. But even prior to participating in ACUPCC, UC had been active by adopting a Sustainable Design Policy in 2001. Construction of its first LEED-certified building was completed in 2006. Princeton Review designated UC as one of the nation’s top green universities in April 2010.

Modeling of UC’s carbon footprint has been undertaken twice, in 2008 and again in 2010, as part of its participation in the ACUPCC. In both cases, the ACUPCC preferred model, the Clean Air- Cool Planet (CA-CP) Campus Carbon Calculator was used. The “comfort level” for 8 of 31 categories of data inputs in the original modeling was considered “low” by the authors. Predominantly, these related to
transportation aspects, mostly commuting and air travel (6 of 9 categories of data inputs for this segment), which were the only Scope 3 emissions included in the original UC footprint.

The 2010 modeling activity was reviewed by a steering committee from the President’s Advisory Council on the Environment and Sustainability (PACES) which is comprised of functional experts from a cross-section of university departments. Required model inputs were assessed and functional experts for each input element were defined based on which department/function controls the operations responsible for that element. Previous modeling was reviewed for background and consistency. Impacts of changes in the university since the previous modeling were assessed, and a new expanded organizational scope was defined.

Data was collected from functional experts and then converted to CA-CP model inputs. In some cases, simple spreadsheet models were created to convert raw data into model inputs. Key vendors supplied data on paper purchases. Commute and non-commute travel inputs were calculated based on a 2008 survey of main campus students, faculty and staff. For some data inputs (particularly offsets from tree planting), literature research was conducted on ways to compute CO₂ equivalents, and a method was chosen based on UC’s specific situation.

The entire process took roughly 8 months, although compilation of source raw data, such as energy generation and use, occurs continually by key functional departments. Compiled input values and modeling results were internally peer-reviewed with functional experts who had supplied the raw data and with members of a steering committee who were not involved in the modeling effort.

During review of results, it was noted that the model as supplied by ACUPCC used internally projected values rather than actual data to compute the 2010 footprint and therefore gave inaccurate results. So, the
model was modified to use its standard formulas to compute 2010 emissions from actual input data rather than the projections.

4.1.3 Definition of Boundaries

All UC operations except Raymond Walters College (RWC) and Clermont College campuses were addressed in the 2010 modeling. This is consistent with UC Human Resources and other reporting of “Main” (or Uptown) campus as differentiated from RWC or Clermont. This reflects the “operational control” approach for choosing boundaries. The only exception is for Holmes Hospital where a 20% share of electricity consumption based on building occupancy was included in the model.

The FY10 modeling included all scopes possible in the CA-CP model. These are:

- Scope 1 - direct emissions from on-site generation of electricity and steam and other stationary combustion sources, university fleet vehicles (mobile emissions), and fugitive emissions (refrigerant use and fertilizer application);
- Scope 2 - emissions from purchased electricity for UC Main campus consumption; and
- Scope 3 - other indirect emissions from faculty, student and staff commuting, directly financed travel by air and other modes, solid waste handling, wastewater treatment, and paper purchases.

Transmission and distribution losses were computed by the model as a separate category (apparently based on kWh used). Offsets from composting and tree planting were included. The model includes other elements that are not relevant for UC, such as purchased steam and chilled water, animal husbandry, and purchased offsets. Specific model inputs are detailed in Appendix A.
4.1.4. GHG Protocol Compliance

Modeling in 2010 followed the Principles of The Greenhouse Gas (GHG) Protocol Corporate Accounting and Reporting Standard (GHG Protocol, 2011) which are shown in italics, followed by a discussion of steps taken to comply with the standard:

- **RELEVANCE:** Ensure the GHG inventory appropriately reflects the GHG emissions of the company and serves the decision-making needs of users – both internal and external to the company.
  
  o The CA-CP model was chosen to allow comparison of UC to peer institutions within ACUPCC. All data elements within the model that are relevant to UC operations were used. However, the CA-CP model does not address all possible Scope 3 emission sources defined in the GHG protocol. Additional Scope 3 sources, and broader UC sustainability impacts beyond carbon footprint, are included in the new Sustainability model developed by this project.

- **COMPLETENESS:** Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusions.
  
  o The boundary for 2009 and 2010 was all sources within operational control of UC except RWC and Clermont campuses. Nothing within this boundary was intentionally excluded. Power associated with buildings outside the model boundaries was subtracted from utilities data to ensure that data inputs matched the boundaries.

- **CONSISTENCY:** Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series.
Where they were known and accurate, data sources and methods used in the initial modeling were used again in the 2010 update. Several new elements in the 2010 version of the model required new inputs to be developed. As detailed elsewhere in this dissertation, a larger boundary and new methods for travel and tree planting were used for 2010 to more accurately reflect actual conditions.

- **TRANSPARENCY:** Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.

  - References and discussion of all data sources and calculation methods are given in Appendix A. Additionally, backup files including all calculation spreadsheets were given to the University architect and the Utilities departments as a guide for future GHG modeling.

- **ACCURACY:** Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

  - All efforts were made to ensure that complete and accurate data within the model boundaries was obtained. While methods for generating transportation and tree planting inputs can still be improved, model inputs represent the best data and estimates currently possible.
4.1.5 Methodology for Updating Previously “Low Comfort Level” Transportation Inputs

For the original modeling, CA-CP transportation data inputs were assumed on the basis of parking decals sold, inflated by a 10% factor for those assumed to park off campus. Most (99%) of students, faculty, and staff using their personal vehicles were assumed to be driving alone, making 1 trip per day, 19 miles per trip, for 200 days per year. Students, faculty, and staff without parking passes were assumed to be commuting by bus. No documentation for transportation inputs indicated how students living on campus were addressed. The air travel estimate was based on data from UC’s travel agency (AAA) inflated by 25% to compensate for tickets purchased from other sources. The reasonableness or basis of these assumptions is not documented. Resulting model input values for student commuting accounted for roughly 75% of the total commute miles, but population data showed them to be only roughly 66% of the total commuter population (including faculty and staff).

A survey of commuting and air travel was also conducted (Moore, 2008), but results came too late to be included in the initial footprint analysis. Survey data is considered by GHG protocol to be primary (observed) data collected from the specific reporting facility, as opposed to secondary data from published sources that are representative of the activity (such as the default IPCC factors that are built into the CA-CP model). Transportation needs and perceptions are frequently assessed through surveys, however Bricka and Bhat (2006) reported that in transportation surveys, adults younger than 30 years of age are associated with significant underreporting. Transportation surveys from Portland State University and Syracuse University are available from the Association for the Advancement of Sustainability in Higher Education (AASHE, 2010).

For updated modeling, data from the transportation survey was used to generate model inputs through a methodology detailed in Appendix A. Respondent information regarding mode (walk, individual vehicle,
carpool, motorcycle, bus, air) of commute and non-commute travel was used directly. Information on commute travel distance had been collected in ranges and was converted into discrete values (midpoints where the ranges had bounds, with an assumption of 60 miles one way as the upper bound). Frequency had not been asked, so assumptions were made in consultation with the PACES oversight committee: for students, 30 weeks (three 10-week quarters) were assumed, 20 weeks for faculty and 47 weeks for staff (52 weeks minus 10 holidays, 2 weeks of vacation and 1 week of sick or miscellaneous time off). Population data for “faculty” includes adjunct, student teaching assistants, and others that would not be commuting daily.

Survey information on non-commute university-related travel gave numbers of respondents by mode (car, bus, train, air) within a range of trips per year (for example, 1-5 trips, 6-10 trips, 11-20 trips, and more than 20 trips), and ranges of distances (local trips were defined in the survey as 20 miles round trip, regional trips defined as 80 miles round trip, US/Canada trips defined as 2500 miles round trip, and international trips were defined as 9000 miles round trip). The midpoints of numbers of trips were used to calculated total miles by mode for modeling input, and assumptions were made for the categories without upper bounds (e.g., for “>20 trips/yr,” 25 trips were assumed; for “>10 US/Canada trips,” 15 trips were assumed; and for “>10 international trips,” 12 were assumed). Because university population had increased since the year the survey was conducted, the computed travel miles were scaled up on a per capita basis to estimate university-wide total miles traveled for the FY09 and FY10 modeling inputs.

Using UC-specific survey data resulted in a large increase in estimated air travel miles (from roughly 1 million to roughly 125 million). As a partial cross-check, data for FY09 and 10 air travel associated with study abroad was obtained from the UC International Studies department. This subset of UC air travel was found to be roughly 12% of the total estimated international travel. This gives an “order of magnitude” confirmation of the estimates, but there is still much uncertainty in the commute and
especially non-commute travel inputs because of much interpolation and extrapolation which was necessary to convert the survey data into model input form. It is recommended that a new transportation survey be conducted for future modeling to obtain data that can be directly used as model inputs.

4.1.6 Discussion of GHG Modeling Results

Modeling results are shown in Figure 4. Years FY2007 and 2008 reflect original modeling, while FY2009 and 2010 reflect updated techniques. Transportation, a Scope 3 emission, was a much larger portion of the updated footprint, roughly 37% rather than 19% as reported in the initial modeling. This was principally due to air travel, which in addition to increases in quantity estimates discussed in the previous section, is unique among the GHG emission categories in that it has additional impact beyond the emitted gases themselves. This additional effect is due to radiative forcing -- the atmospheric effects of contrails, aerosols, and cirrus clouds contributed by aviation. The Intergovernmental Panel on Climate Change (Forster et. al., 2007) has defined a multiplier factor of 2.8 to be applied to air travel mileage to account for this additional warming, beyond the GHG emissions. The combination of increased air travel miles multiplied by the radiative forcing factor resulted in the apparent large difference for transportation between the original and updated modeling.
Figure 4. Detailed Comparison of Relative Contributions of Types of GHG Emissions and Details of Energy and Transportation Impacts, 2007–2010.

Other differences between original and updated modeling included:

- FY09 and 10 has an expanded geographic scope from East & West Campuses (2008) to essentially all non-RWC and Clermont. This included the Genome Institute, Center Hill research facility, and many new structures built since 2008. Total square footage values were
  - 2008 = 12,574,783;
  - 2009 = 13,705,694; and
  - 2010 = 14,322,628.
Lists of individual buildings were carefully considered to ensure that utilities consumption data used for modeling reflects all the buildings currently being considered within the model scope.

- Population numbers for students, faculty and staff used for 2008 “Uptown” footprint actually comprised the total university including RWC and Clermont. This caused normalized results in “metric tonnes of CO2 equivalents per full time student” to be lower than it should have been for 2008. For 2010 the population data matched the operational boundary which was Main campus, but not RWC or Clermont.

- The version of the CA-CP model used in FY09 and 10 (CA-CP version 6.4) has additional elements not covered in the previous model (CA-CP version 5): wastewater, which added less than 1 MT; paper purchases, which added roughly 500 MT; and electricity transmission and distribution (T&D losses) which added roughly 20,000 MT.

- FY09 and 10 also credit a smaller offset for tree planting, roughly 200 MT rather than 1014 MT as previously reported, due to an apparent difference in method of calculating. The method used for 2008 is unknown, but the number of trees planted in 2009 was more than in 2008, so offsets would have been higher if the method was consistent. The method used for 2010 reflects a calculation method based on individual trees, which was the only raw data available. More rigorous estimating methods are possible with additional input data, and are recommended for future modeling efforts.

- Budget values relating to operating, research and energy budgets for FY09 and 10 were reported in 2005 dollars as required by the model. This makes them appear smaller than values reported on the UC website and for previous modeling which had been in actual year dollars.

- Additionally, during FY10 much of the electricity was supplied from natural gas combusted at the UC internal cogeneration plant (which is considered a Scope 1 source). This decreased the overall energy carbon footprint compared to FY09 when the cogeneration plant was minimally run due to
high natural gas prices and most electricity was purchased from Duke Energy which is produced from coal combustion (which is a Scope 2 source). As a result, both the magnitude and distribution of GHG emissions changed.

Attempts were made to compare carbon footprint results for UC with other organizations: specifically the City of Cincinnati and other universities. Estimated that total GHG emissions for the City of Cincinnati (Cincinnati, 2008) were 8.5 million tons of CO₂e in 2006. This would be equivalent to roughly 7.7 million MT CO₂e. The UC total of roughly 466,000 MT CO₂e (average of FY09 and FY10) would represent nearly 6% of the City total emissions. City emission sources were approximately 60% from buildings (40.7% from commercial and 18.6% from residential), nominally 27% from transportation, and 16% from industrial operations, with waste disposal providing an offset of 1.5% (perhaps due to landfill methane recovery and recycling, although it is not explicitly stated in the report). This equated to 25.5 tons (or 23.1 MT) per capita, which was higher than the national average at that time of 24.5 tons per person. This compares to UC average over FY 2009 and FY 2010 of 9.3 MT CO₂e per person including full time, part time and summer school students, plus faculty and staff; or 10.9 MT CO₂e per student. Comparison between UC and the City did not yield useful insights due to the different natures of the organizations. For example, comparison on a per capita basis would be expected to be less at the university for non-residential people, because it only reflects GHG emissions from a portion of their day.

Comparison with other universities was also problematic. Reports for other participants in ACUPCC, and for those who publish GHG reports or data, show wide variation in total emissions. Normalizing by square footage or by student also result in variations which could be due to differences in the climate (number of heating degree days or cooling degree days affect energy consumed for building heating and cooling), nature of the university (research labs would be expected to consume more energy per square foot than standard classrooms), nature of student body (transportation emissions would be higher for commuter campuses vs. those with higher percentage of students in residence), the predominant source of
power (coal produces more GHG emissions than hydropower or natural gas), and many other variables. Additionally, some institutions that used the CA-CP model did not apparently include all data inputs. For example, no air travel emissions were reported for Ohio State during 2008 (The Ohio State University, 2009). Although direct comparison was not shown to be meaningful, when expressed as gross metric tons per 1000 square feet of buildings, UC’s emissions are roughly 33 (average of FY2009 and 2010), while Ohio State’s emissions for FY2008 were reported as 29 (The Ohio State University, 2009). It is likely that differences in carbon footprint of institutions are more due to structural differences in the institutions (location, research mission, commuting patterns, etc.) and the degree of thoroughness in accounting for all emission sources in the estimate, rather than a comparative measure of GHG management programs. For example, due to accounting differences between methodologies of UC carbon footprint modeling, total emissions for FY09/10 were higher than reported in 2008. But emissions from the energy category, normalized per thousand gross square feet of campus buildings, declined from 23.97 to 21.66, as shown in Table 3. However, a more detailed review would be needed to determine whether to attribute the reduction to energy efficiency measures in individual buildings, or differences in weather conditions during those particular years.
Table 3. Comparison of Energy Emissions Normalized Per Square Footage of Total Campus Buildings

<table>
<thead>
<tr>
<th>Reporting Year</th>
<th>Total GHG Emissions (MT/CO₂e)</th>
<th>Total GHG Emissions – Energy Category (MT/CO₂e)</th>
<th>Campus Buildings (Gross Square Feet, GSF)</th>
<th>Energy Emissions (MT/CO₂e)/1000 GSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>372,309</td>
<td>301,479</td>
<td>12,574,783</td>
<td>23.97</td>
</tr>
<tr>
<td>2009</td>
<td>477,426</td>
<td>318,739</td>
<td>13,705,694</td>
<td>23.25</td>
</tr>
<tr>
<td>2010</td>
<td>455,526</td>
<td>287,363</td>
<td>14,322,628</td>
<td>20.06</td>
</tr>
<tr>
<td>Average 09/10</td>
<td>466,476</td>
<td></td>
<td></td>
<td>21.66</td>
</tr>
</tbody>
</table>

Eagan et al. (2008) estimate that a university’s GHG inventory would more than double if other Scope 3 emissions were included. Additional work by Huang et. al. (2009) estimated that GHG emissions from the education sector comprise:

- Scope 1 direct emissions ~ 15%,
- Scope 2 from purchased electricity ~ 20%,
- Scope 3 other indirect:
  - From commuting ~ 25%,
  - From the top 10 suppliers ~ 17%, and
  - From other indirect sources ~ 23%.

This could be roughly equated as 35% energy, 25% transportation, and 40% other indirect emissions. Given that UC’s estimated GHG emissions comprise roughly 63% energy and 37% transportation, it would appear that large portions of our actual carbon footprint are still unaccounted for. Although efforts were made to obtain input data from all university sources, it may be possible that some was missed. Departments use P-cards to obtain items such as paper, and services such as travel, that can impact the footprint but are not tracked through the purchasing system. By approaching specific departments who are assumed to have relevant data, other sources of input data might be inadvertently excluded.
A more thorough approach would be using a life-cycle assessment to comprehensively assess activities of all University departments, and considering supplier impacts, to uncover how they contribute to the carbon footprint. Then, work to include these impacts into the carbon footprint model, rather than working “from the back end” -- looking at model inputs and trying to define which departments might have data.

4.1.7 Recommendations for Future Carbon Footprint Modeling Work

- Conduct a new transportation survey.
  - Focus on gathering data from a representative cross-section of the UC population including balanced student/staff/faculty, co-ops, graduate vs. undergraduate students, and other subgroups that may have different commuting patterns.
  - Keep raw data survey results with sufficient identifiers to allow analysis of sub-populations and conversion into model inputs (total miles by mode and by student/faculty/staff) with minimal interpolation or extrapolation.
  - Particularly seek data from departments and functions likely to have significant travel (such as the athletic department, other groups who travel for competitions, international studies, and professors with international research projects or students who present at international conferences).
  - Consider cross-checking estimates of non-commute travel against a sampling of expense reimbursement reports, extrapolated to estimate the entire university population.
- Refine estimates of re-forestation offsets
  - Work with Cincinnati Urban Forestry tree canopy photos or other data sources, or develop estimation methods to allow use of more thorough methods of computing offsets from tree planting.
- Consider using a life-cycle assessment approach to comprehensively assess activities of all University departments to uncover how they contribute to the carbon footprint. Then, work to include these impacts into the modeling activity.

### 4.2 OBJECTIVE 2: Creation of Comprehensive Sustainability Framework

#### 4.2.1 Overview

The University’s scope of impact on the economy, environment, and society extends beyond GHG emissions and into the realm of sustainability factors considered by the UN Brundtland Commission (UN, 1987). This is often called the “triple bottom line” of economy, environment, and social equity. Many current sustainability assessment systems exist, including the Global Reporting Initiative (GRI, 2006), United Nations (UN) Millennium Development Goals (UN, 2008), UN Commission on Sustainable Development (CSD) indicators (UN, 2007), and USEPA Report on the Environment (ROE) indicators (USEPA, 2008). Together they address hundreds of aspects of sustainability, but have different utilities based on operational scope, data requirements, and other factors. Many of these aspects relate to the UC setting, which is similar to a small city in scope of services provided, such as housing, food, and transportation; its economic impact as one of the largest employers in Cincinnati; and its unique social impact through its educational and research missions.
4.2.2 Discussion of Sustainability Systems

A comprehensive set of sustainability metrics was defined for UC by analyzing a variety of systems in wide use. Each system assessed, and its applicability to the university setting, is discussed in the following:

The Global Reporting Initiative (GRI)

The GRI framework (GRI, 2006) claims to be the most widely used sustainability reporting system in the world. As of September 21, 2011, current reports were available for nearly 700 organizations, with over 1800 reports submitted since the program began in 1998. Reporting organizations include private and state-owned companies, non-profit organizations and public institutions in more than 30 sectors, including five universities worldwide. US universities reporting in the GRI for 2010 are Ball State University and Western Kentucky University.

Reports include discussion of conformance to defined reporting principles (balance, comparability, accuracy, timeliness, clarity, and reliability) and a set of Standard Disclosures. Three types of disclosures are required in GRI reports; Organization Profile, Management Approach, and Performance Indicators. Each has specified content. Only the GRI Performance Indicators were assessed for this project. They comprise three groups: economic, environmental, and social; with the social indicators subdivided into labor practices, human rights, product responsibility, and society categories. In all segments, some indicators are designated as “core” and others as “additional.” Both core and additional indicators were reviewed for this project.

In addition to the base GRI indicator set, specialized indicators are available for organizations in 15 sectors. Sectors potentially relevant to UC include Electric Utilities, because UC generates electricity on-
site, and Public Agency, since the university is a public institution. Therefore, indicators for these sectors were included in the project.

**The United Nations Millennium Development Goals (MDG)**

The UN MDG (UN, 2008) are a series of performance targets at a country level relating to specified economic, environmental and social goals. For example, to “halve between 1990 and 2015, the proportion of people who suffer from hunger,” “reduce biodiversity loss,” and “make available the benefits of new technologies, especially information and communications.” While they do not strictly apply to a university, many can relate to the university research and education mission. Being aware of these global goals can guide a university to create education, outreach or tools that address these challenges. Additionally, goals in some areas such as reducing biodiversity loss can be applied at the university scale to address aspects and property under control of the institution.

**The United Nations Commission on Sustainable Development (CSD)**

The UN CSD indicators (UN, 2007) focus on 14 themes across economic, environmental and social topics and are intended to guide international agencies and individual countries in defining sustainability programs. Some, such as education and literacy, relate directly to the university mission. Others such as housing and crime relate to logistical issues faced at the campus. Additionally, environmental indicators such as air quality and water and land use are relevant due to impacts from university operations.

**EPA Report on the Environment (ROE)**

The United States Environmental Protection Agency (USEPA) Report on the Environment (ROE) indicators (USEPA, 2008), were defined to present information about environmental health and human health effects of environmental conditions.
Some elements are not as applicable to the main campus due to its urban setting, but would be more relevant for branch campuses, particularly Clermont, which is surrounded by undeveloped land. Examples are streambed stability, macroinvertebrates, and nitrogen/phosphorous levels in wadeable streams. Others, such as contaminant levels in ambient air, are affected by multiple sources, and UC would be just a single contributor. Even so, such indicators could be used by assessing and controlling the UC impact on the combined contaminant level.

Interestingly, the ROE indicators included nine health conditions which are considered social factors by other sustainability systems, but which could be markers/health effects associated with exposure to environmental pollution.

**Advancement of Sustainability in Higher Education STARS Sustainability Tracking, Assessment & Rating System (AASHE STARS)**

AASHE STARS (AASHE, 2010) is a self-reporting framework created to guide universities in assessing and improving their sustainability performance according to weighted credits for specified activities. It is similar to LEED (USGBC, 2009), offering a menu of points for a series of more than 70 credits in the categories of Education & Research; Operations; Planning, Administration and Engagement; and Innovation. Depending on total points achieved, a rating of bronze, silver, gold, or platinum is attained for a fee and would represent external recognition of an institution’s sustainability program against a common set of criteria.

**The Princeton Review Green College Ratings**

The Princeton Review Green College Ratings (Princeton Review, 2011) were based on ten factors to assess institution policies, student experience on campus, and student preparation for the future. It
addresses topics relating to educational offerings, student engagement in environmental issues, and assessment and minimization of institutional waste, GHG, energy and transportation impacts.

**The Sustainable Endowments Institute Campus Green Report Card**

The Sustainable Endowments Institute Campus Green Report Card (Sustainable Endowments Institute, 2011), as its sponsoring Institute would imply, focuses on economic and investment implications of sustainability. It computes a “grade” based on scores reflecting status against a list of fifty-two indicators in nine categories which are weighted “based on the indicator's impact on overall campus sustainability and relative importance compared to others within the category.” Some indicators list multiple activities needed to attain full credit for the category. Each activity was assessed separately in this project.

**The University of Cincinnati 2019 Strategic Plan**

The UC 2019 Strategic Plan (UC, 2010) sets forth specific goals in eight areas deemed critical to institutional success. Defined areas are Learning, Discovery, Community, Economy, Global Engagement, Mission-based Health Care, Collaboration and Sustainability. Sustainability goals are:

- Reduce carbon footprint,
- Achieve 70% recycling rate as a percentage of total waste stream,
- Attain an A- or better grade on the College Sustainability Report Card, and
- Increase attendance at sustainability programming and outreach activities.

Unfortunately, some goals in other areas of the UC 2019 Strategic Plan will likely have the effect of increasing the carbon footprint, which works against the sustainability goal. These include increasing attendance at campus events and increasing the number of students studying abroad, which would directly increase transportation-related GHG emissions. Sustainability planners should be aware that extra GHG reductions will be needed to compensate for the effects of achieving these other goals.
4.2.3 Definition of Sustainability Framework

In total, 621 indicators, as summarized in Table 4, were assessed for potential applicability to the university setting relative to:

- coverage across the spectrum of environmental, economic, and social factors,
- scope limitations relative to the University operations,
- data limitations—current sources for data or issues relating to developing data, and
- clarity and utility of output as management tools in the university setting as performance aspects over which the university has control and which are easily understood.

A new customized set of metrics was defined to reflect comprehensive sustainability performance for the university. A full comparison of the individual indicator sets showing the indicators assessed and the ones selected for the final UC sustainability framework is given in Appendix C.
Table 4. Comparison of Indicator Systems Assessed

<table>
<thead>
<tr>
<th>Number of Indicators Assessed</th>
<th>GRI(^1)</th>
<th>UN MDG/CSD(^2)</th>
<th>USEPA ROI(^3)</th>
<th>AASHEE STARS(^4)</th>
<th>PR GC(^5)</th>
<th>SEI CRC(^6)</th>
<th>UC 2010(^7)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>34</td>
<td>23</td>
<td>0</td>
<td>18</td>
<td>2</td>
<td>22</td>
<td>25</td>
<td>124</td>
</tr>
<tr>
<td>Environmental</td>
<td>53</td>
<td>49</td>
<td>44</td>
<td>62</td>
<td>6</td>
<td>41</td>
<td>2</td>
<td>257</td>
</tr>
<tr>
<td>Social</td>
<td>74</td>
<td>43</td>
<td>10</td>
<td>58</td>
<td>3</td>
<td>17</td>
<td>35</td>
<td>240</td>
</tr>
<tr>
<td>Total</td>
<td>161</td>
<td>115</td>
<td>54</td>
<td>138</td>
<td>11</td>
<td>83</td>
<td>59</td>
<td>621</td>
</tr>
</tbody>
</table>

\(^1\) Global Reporting Initiative Sustainability Reporting Guidelines, combination of G3, Electric Utility and Public Agency indicators.
\(^2\) United Nations Millennium Development Goals and Commission for Sustainable Development Indicators.
\(^3\) United States Environmental Protection Agency Report on the Environment Indicators.
\(^4\) Association for the Advancement of Sustainability in Higher Education Sustainability Tracking, Assessment & Rating System, Version 1.0
\(^5\) Princeton Review Green College (GC) criteria. While the GC has only ten criteria, the one on GHG is a compound indicator of computing a GHG inventory and having a reduction plan. These elements were counted separately for the assessment project.
\(^6\) Sustainable Endowments Institute. College Sustainability Report Card 2011
\(^7\) University of Cincinnati UC2019 Strategic Plan

The only indicator listed in all 7 systems was conducting a GHG inventory. Other indicators frequently considered, and the number of systems that addressed them, were:

- minimizing transportation impacts (5),
- waste reduction (5),
- adult learning -- college and beyond (5),
- energy efficiency for buildings and equipment (4),
- water use intensity (4),
- local and environmentally preferred spending for supplies and food (4),
- renewable energy sources, and reducing fossil fuels (4), and
• initiatives to reduce GHG emissions (4).

Topics with highest numbers of related indicators were:
• minimizing transportation impacts (30),
• health status and risks (23),
• waste reduction (20),
• energy efficiency for buildings and equipment (19),
• economic performance (17),
• adult learning (15),
• sustainability curriculum (15),
• ambient air quality (14), and
• a tie between research and development activity, responsible investing and investment transparency, and sustainability policy and planning (12 each).

Based on the assessment of applicability and usefulness of the indicators to UC, a sustainability metric set was created concentrating on those aspects that apply directly to the university and are strategic, measurable, actionable, relevant and time-bound. Items chosen to comprise the new sustainability framework are shown in Appendix C with dark highlighting. The new sustainability footprint addresses 87% of the assessed economic indicators, 72% of the environmental indicators, and 80% of the social indicators in a consolidated format that makes them more useful as a management tool. In total, the new sustainability footprint covers 78% of the assessed indicators. There was no existing metric set that covered all the relevant indicators. The best match was GRI, which addressed 69% of the content relevant for UC, second was AASHE at 40%. All of the UC 2019 goals are related to topics that are addressed in
the new sustainability indicator framework. Transparency and regulatory compliance are cross-cutting themes for all three indicator areas.

Many of the new framework elements are composites of several related aspects that had been separate indicators in other systems. An example is the new framework element “Percent of local and environmentally preferable (including fair trade) spending for supplies, including food” which summarizes seven different indicators from four separate systems.

Sources of data to gauge UC performance against each element of the new framework were sought. Many of the elements relate to existing regulatory requirements or voluntary programs at UC, so it is probable that information is kept. However, insufficient data was publicly available to measure current performance of UC against the full set. Due to overlap of elements between the UC 2019 Strategic Plan and the new sustainability framework, it is likely that performance data will be compiled and made public in the future as the Strategic Plan is implemented. From analysis of the indicator systems, it is also likely that progress on the UC 2019 Strategic Plan will yield recognition on external systems such as AASHE STARS.

4.2.4 Recommendations for Future Sustainability Footprint Work

As global awareness and understanding of sustainability evolves, the source indicator sets could change. UC should stay aware of this global context and review the sustainability framework elements over time, and revise it as needed to keep it a useful tool for driving performance improvement.
4.3 OBJECTIVE 3: Development of Decision-making Model

A number of mitigation options had previously been defined for UC based on the initial carbon footprint. These were compared to a new set of mitigation options that were developed based on the new sustainability framework. The goal of the comparison was to assess whether more effective allocation of human and financial resources results from taking a holistic view and capitalizing on the synergies that exist between the three aspects of sustainability: economic, environmental and social performance.

4.3.1 Climate Action Plan Carbon Footprint Mitigations

Actions to reduce GHG emissions had been defined by UC PACES based on the previous CA-CP modeling. In many cases, potential actions were listed but no associated costs or emissions reductions were shown. The most complete listing of mitigations was in the Energy Conservation Measure Survey (UC 2009, p.230 - 231). It included 107 projects defining:

- project name, which generally defined a specific building where the action would be taken;
- project type, which categorized according to main purpose of the action such as heating, ventilation and air conditioning (HVAC) system improvement, or lighting upgrade;
- project cost ($);
- electricity reduction (kilowatt hours, kWh);
- natural gas reduction (thousand cubic feet, Mcf);
- annual cost reduction ($); and
- simple payback period (years).
Not all of the listed actions had associated GHG reductions. Some were asbestos abatement and fire protection system upgrades, or plumbing fixture replacements. Utility cost reductions were listed for the latter type. The list is summarized by project type in Table 5 and by building in Table 6. Related maps showing buildings color coded to indicate energy consumption were presented in the Climate Action Plan, and are included here as Appendix D.

<table>
<thead>
<tr>
<th>Project Type</th>
<th>#</th>
<th>Total Project Costs for Type</th>
<th>Total Electricity Use Reduction (kWh)/yr</th>
<th>Total Natural Gas Use Reduction (Mcf)/yr</th>
<th>Total Utility Cost Reduction/yr</th>
<th>Simple Payback (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Envelope</td>
<td>5</td>
<td>$4,450,000</td>
<td>4,550,000</td>
<td>9,200</td>
<td>$369,350</td>
<td>12</td>
</tr>
<tr>
<td>Air Handling</td>
<td>14</td>
<td>$48,825,000</td>
<td>46,858,364</td>
<td>67,790</td>
<td>$4,373,964</td>
<td>11</td>
</tr>
<tr>
<td>Fans, pumps, motors, auxiliaries</td>
<td>12</td>
<td>$8,970,000</td>
<td>8,964,150</td>
<td>26,250</td>
<td>$833,670</td>
<td>11</td>
</tr>
<tr>
<td>Occupancy sensors</td>
<td>17</td>
<td>$18,698,000</td>
<td>24,223,000</td>
<td>22,677</td>
<td>$1,810,911</td>
<td>10</td>
</tr>
<tr>
<td>Lighting</td>
<td>21</td>
<td>$2,130,000</td>
<td>5,920,961</td>
<td>0</td>
<td>$384,863</td>
<td>6</td>
</tr>
<tr>
<td>Domestic Water Heater</td>
<td>7</td>
<td>$375,000</td>
<td>0</td>
<td>12,040</td>
<td>$96,320</td>
<td>4</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>12</td>
<td>$5,910,000</td>
<td>6,205,000</td>
<td>35,950</td>
<td>$690,916</td>
<td>9</td>
</tr>
<tr>
<td>Unrelated to GHG</td>
<td>19</td>
<td>$10,117,000</td>
<td>n/a</td>
<td>n/a</td>
<td>$75,863</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>107</td>
<td><strong>$99,475,000</strong></td>
<td><strong>109,221,475</strong></td>
<td><strong>173,907</strong></td>
<td><strong>$8,635,857</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 6. UC GHG Mitigation Options – Summarized by Building

<table>
<thead>
<tr>
<th>Building</th>
<th># actions</th>
<th>Total Project Costs for Building</th>
<th>Total Electricity Use Reduction (kWh)/yr</th>
<th>Total Natural Gas Use Reduction (Mcf)/yr</th>
<th>Total Utility Cost Reduction/yr</th>
<th>Simple Payback (yr)</th>
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<td>$7,995</td>
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<td>1,500,000</td>
<td>31,250</td>
<td>$347,500</td>
<td>3</td>
</tr>
</tbody>
</table>

| Total                     | 107       | $99,475,000                       | 109,221,475                              | 173,907                                 | $8,635,857                    |                    |

In the Climate Action Plan, electricity and natural gas savings were estimated for many of the listed options, and simple payback period was listed. However, Net Present Value (NPV) calculation allows comparisons that account for savings associated with some of the options.
NPV is calculated by equation 1

\[ \text{NPV} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} - C_0 \]  

Where:

\( t \) = time intervals being considered (in our case, 10 annual periods)

\( C_t \) = payments or income at each interval (in our case, annual projected savings from implementing a project)

\( r \) = discount rate (the rate of return that could be earned on money invested during the time period being considered),

\( C_0 = \) initial cost

NPV calculations can also address maintenance expenditures or other costs and savings over a project life, but this degree of detail was not available for all options. So a simplified NPV was conducted, considering only estimated capital cost and estimated annual savings. For this project, NPV was calculated over a 10-year life, which might be conservative for some of the measures, using a constant 5% discount rate. This resulted in an approximate NPV.

Additional fields were computed to perform prioritizations for this project:

- GHG reduction (MT CO₂e) was computed from stated factors in the Climate Action Plan (UC 2009, p. 79) of
  - 0.778 tonnes CO₂e saved per Mwh for electricity consumption reductions and
  - 0.1025 tonnes CO₂e saved per MMBTU steam reduction.

- GHG reduction per initial project cost $

- GHG reduction per NPV $

Results showing the original Climate Actions and the additional computed fields are in Appendix E.
4.3.2 Sustainability Action Plan

Potential actions for sustainability performance improvement were defined depending on the thrust of each element in the new framework. For most of the economic and social elements, the actions involved expanding existing programs to include sustainability considerations, or developing new programs. Actions proposed for such elements were usually data collection and analysis to gauge current performance status. For several environmental elements, notably energy and water consumption reduction, concrete projects were defined involving implementing new technology-based improvements.

Energy and water consumption opportunities and their costs and benefits were identified by several means including:

- the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Energy Design Guides:
- RS Means Facilities Construction Cost Data 2011 (Mossman, 2010),
- Laboratories for the 21st Century (Labs 21, 2011),
- The Energy Efficiency Manual (Wulfington, 1999), and
• personal conversations with equipment suppliers.

A spreadsheet was created listing technologies in addition to the Climate Action Plan GHG reduction strategies that could potentially be used to reduce energy and water consumption. Energy is used in several forms at UC, including:

• electricity – used principally for lighting, or operating pumps, fans, motors and other equipment related to building systems (such as HVAC), or operations conducted in the buildings including fixed equipment and “plug load” associated with a variety of items;
• natural gas – consumed at the Central Utility Plant and East Utility Plant to generate electricity, steam and chilled water; and used directly in many buildings for water and space heating or other building process use;
• steam – used for water and building heating and for some equipment; and
• chilled water – used for cooling buildings and some equipment.

Domestic water is used for a variety of purposes including drinking, sanitary fixtures, cooling, cleaning, irrigation, and other typical domestic uses; process use in laboratories; and for generating steam and chilled water.

To assess potential impacts and define best locations to deploy the technologies, utility consumption by building was analyzed. A spreadsheet was created listing each structure on Main Campus that was part of the scope for GHG modeling, and compiling monthly utilities consumption for each month during FY 2009 and FY2010. These years were chosen since they were the time period reflected by the updated GHG modeling. Data included were:

• electricity (kWh) total usage from on-site cogeneration plant and purchased,
• natural gas (million British thermal units, MMBtu),
• steam (kilo-pounds, Klb),
• chilled water (ton-hr), and
• domestic water (hundred cubic feet, ccf).

Not all buildings use each type of utility, and meters are not present for all utilities in all buildings. For some structures, there are multiple metering points that were combined to compute the building total utility consumption. Overall, there is a wealth of utilities data for UC due to proactive management of the utilities function. Appendix F presents the results of this utility use analysis.

Utility consumption per building was normalized by gross square footage, and is included in Appendix F. For dorms, utility consumption was also normalized by resident as shown in Table 7.

### Table 7. Dorm Utility Consumption Normalized by Resident

<table>
<thead>
<tr>
<th>Building</th>
<th>Usage Type</th>
<th>Gross Square Feet</th>
<th>Dorm Residents</th>
<th>FY09&amp;10 avg. total energy (MMBtu)</th>
<th>FY09&amp;10 avg. total energy (MMBtu)/resident</th>
<th>FY09&amp;10 avg. total energy (MMBtu)/GSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calhoun Hall</td>
<td>Residence</td>
<td>172,967</td>
<td>680</td>
<td>31,644</td>
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<td>300</td>
<td>7,419</td>
<td>25</td>
<td>0.0951</td>
</tr>
<tr>
<td>Daniels</td>
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<td>148,041</td>
<td>700</td>
<td>22,137</td>
<td>32</td>
<td>0.1495</td>
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<td>Jeff Res</td>
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<td>0.0837</td>
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<td>Siddall</td>
<td>Residence</td>
<td>121,409</td>
<td>450</td>
<td>20,333</td>
<td>45</td>
<td>0.1675</td>
</tr>
</tbody>
</table>

Additionally, to identify candidate buildings for solar reflectance or green roofs, aerial photographs (CAGIS, 2011) of East and West Campus were reviewed. Examples are shown in Appendix G. From
observing the color and shape of the roof for each building, it was possible to determine if a solar reflectance roof was already in place, or if the roof shape was not amenable to that technology.

### 4.3.2.1 Estimating Energy Embodied in Supplied Water

USEPA, the US Department of Energy, and others are giving attention to the water-energy nexus, recognizing that potentially significant amounts of energy are being used for pumping raw water, producing treated water, then pumping it through the distribution system. This energy use represents Scope 3 GHG emissions for entities such as UC using purchased water. The Electric Power Research Institute (EPRI) estimates that roughly 4 percent of the nation’s electricity consumption is used for moving or treating water and wastewater (EPRI, 2000). Studies in the United States show wide variation, with one estimate from California indicating that water represents 19% of all electricity consumed in the state (California Energy Commission, 2005). Barry (2007) provides various factors for energy intensity in supplied water, which is measured in kilowatt hours (kWh) of electricity per cubic meters (or per million gallons) of water. This can then be combined with generic or local utility-specific factors of GHG emissions per kWh to define the Scope 3 GHG emissions associated with water use.

The US Department of Energy (EIA, 2001) estimates that an additional 9 to 25% of household energy (depending on the source of energy) is used to heat water for domestic uses such as cooking and cleaning. This would apply to hot water used in UC residence halls, cafeterias, and other locations. Emissions from energy used for heating water would already be accounted for in the UC footprint as Scope 2 electricity purchases. Reducing water use – particularly hot water -- would help reduce the carbon footprint in multiple ways, although the footprint associated with supplied water is not currently considered.
UC obtains domestic drinking water from the Greater Cincinnati Water Works (GCWW) which uses the following sources:

- surface water from the Ohio River treated at the Miller Plant (88%), and
- groundwater treated at the Boulton Plant in Butler County (12%).

Unsuccessful attempts were made to obtain data from GCWW on energy consumption for water treatment and pumping to Clifton for distribution at UC. Therefore, factors from the Electric Power Research Institute (EPRI 2002) study of U.S. electricity consumption for water supply were used. EPRI reports that electricity consumption for surface water treatment plants depends on the capacity of the plant, with those treating 100 or more million gallons per day (MMGPD) consuming on average 1,407 kWh/MMgal (million gallons). The Miller Plant has a treatment capacity of over 100 million gallons per day, so this value was used to represent energy required for treatment from GCWW surface water sources. EPRI reports that treatment from groundwater sources consumes an average of 1,824 kWh/MMgal and is independent of the size of the treatment plant, with most of the consumption being due to pumping the water up to the ground surface for use.

EPRI also reported that pumping requires 40 to 80 kWh to lift one million gallons of water 10 feet, depending on efficiency of the pumps. A value of 60 kWh/MMgal was used for the estimate. From the Cincinnati Area Geographical Information System (CAGIS 2011), the elevation at UC is roughly 820 feet above mean sea level, and the Ohio River water surface elevation at the Miller Plant is roughly 465 feet. This means that treated water must be lifted roughly 335 feet to reach UC.

While GCWW uses a surface water source (1407 kWh/MMgal) and a groundwater source (1824 kWh/MMgal), due to proximity, it was assumed that all the water used at UC comes from the Miller Plant. Therefore, by equation 2 total embedded energy in water supplied by GCWW to UC is
\[
\frac{1.407 \text{ kWh}}{\text{MM gal}} + \frac{60 \text{ kWh}}{\text{MM gal lifted 10 ft}} \left( \frac{235 \text{ feet}}{10 \text{ feet/life}} \right) = \frac{3.417 \text{ kWh}}{\text{MM gal}}
\]  \[2\]

Energy conversion factors from the Department of Energy Energy Information Agency (EIA 2011) provide that 1 kWh = 3412 Btu or 0.003412 million Btu (MMBtu).

Therefore, energy embedded in domestic water supplied to UC by GCWW, computed as shown in equation 3, is 11.66 MMBtu/MM gal.

\[
\frac{3.417 \text{ kWh}}{\text{MM gal}} \left( \frac{3.008412 \text{ MMBtu}}{\text{kWh}} \right) = 11.66 \frac{\text{MMBtu}}{\text{MM gal}} \]  \[3\]

Since 100 cubic feet of water (1 ccf) contains 748 gallons of water (or 0.000748 MMgal), this embedded energy also equates to 2.56 kWh/ccf and 0.00872 MMBtu/ccf., as shown in equations 4 and 5.

\[3.417 \frac{\text{kWh}}{\text{MM gal}} \left( \frac{0.000748 \text{ MMgal}}{\text{ccf}} \right) = 2.56 \frac{\text{kWh}}{\text{ccf}} \]  \[4\]

\[11.66 \frac{\text{MMBtu}}{\text{MM gal}} \left( \frac{0.000748 \text{ MMgal}}{\text{ccf}} \right) = 0.00872 \frac{\text{MMBtu}}{\text{ccf}} \]  \[5\]

This factor was used to calculate GHG emission reduction associated with reducing water consumption via the following logic. Electricity for GCWW treatment and pumping is supplied locally by Duke Energy which produces 0.000701546 MT CO₂e per kWh according to the CA-CP modeling results. Therefore, by equation 6, reducing 1 MMgal of domestic water at UC will save 2.397 MT of CO₂e

\[3.417 \frac{\text{kWh}}{\text{MM gal}} \left( \frac{0.000701546 \text{ MT CO₂e}}{\text{kWh}} \right) = 2.397 \frac{\text{MT CO₂e}}{\text{MM gal}} \]  \[6\]

Since the water consumption data for UC buildings is kept by ccf, the factor computed through equation 7 was used in project calculations to assess effects of domestic water mitigation options.
4.3.2.2 Estimating GHG Impact Associated with Each Utility

Data for each of the utility inputs to UC buildings is kept in a different unit. Converting all energy inputs to a common unit allowed computing total energy usage of each UC building so they could be compared and prioritized for actions. For this study, a common unit of MMBtu was calculated as shown below:

- electricity (kilowatt-hours, kWh)
  
  Per the EIA (EIA, 2011), 1 kWh = 3412 Btu or 0.003412 MMBtu;

- natural gas (Million British thermal units, MMBtu) – no conversion needed;

- steam (kilopounds, klb)
  
  One klb of steam is equivalent to 1 MMBtu;

- chilled water (ton-hr)
  
  A refrigeration “ton” is the amount of heat removed by a refrigeration system that would melt 1 ton (2000 lb) of ice in 24 hours, and is 12,000 Btu/hr. Therefore, 1 ton-hr = 12,000 Btu, or 0.012 MMBtu;

- domestic water (hundred cubic feet, ccf)
  
  Energy embedded in 1 ccf of supplied water was derived in the previous section as 0.00872 MMBtu/ccf.

Converting all utility inputs to a common unit allowed computing total energy usage of each UC building, so they could be compared and prioritized for actions.
To calculate the saved cost for utility use reductions, values for each utility came from their individual UC monthly billing spreadsheets averaged over FY09 and 10 and are summarized below:

- Electricity - 0.085985 $/kWh
- Natural gas - 8.721125 $/MMBtu
- Water - 3.71494 $/ccf
- Steam - 23.285 $/klb
- Chilled water - 0.242 $/ton-hr

Comparing GHG emission impacts of reductions in use by the various utilities was based on the output of GHG modeling, in MT CO\textsubscript{2}e associated with each category of energy. Data for all seven years of modeling, (2004 – 2010) were analyzed and ratios of MT CO\textsubscript{2}e emissions per unit of energy input were computed and averaged. The only unique utility was electricity use, because at UC it can be produced at the co-gen plant from natural gas or purchased from Duke which originates from coal combustion. A weighted average of the CO\textsubscript{2}e emissions was calculated for each year depending on the balance between generated and purchased electricity. This evaluation is shown in Appendix H. Computed GHG emissions per unit of utilities were:

- Electricity - 0.000571 MT CO\textsubscript{2}e /kWh
- Natural gas - 0.05290 MT CO\textsubscript{2}e /MMBtu
- Water – 0.00179 MT CO\textsubscript{2}e /ccf
- Steam – 0.0754 MT CO\textsubscript{2}e /klb
- Chilled water - 0.0009 MT CO\textsubscript{2}e /ton-hr
4.3.2.3 Defining Costs and Benefits of Potential Sustainability Actions

Potential actions to improve performance against each of the sustainability criteria were assessed and are shown in Appendix I.

For each action, the following information was computed and compared:

- Initial cost ($),
- Natural gas savings (MMBtu),
- Electricity savings (kWh),
- Water savings (ccf),
- Steam savings (klb),
- Chilled water savings (ton-hr),
- Total utility savings ($),
- Total GHG savings (MT CO₂e),
- Simple payback (yrs),
- NPV ($),
- # Economic indicators impacted,
- # Environmental indicators impacted, and
- # Social indicators impacted.

Additionally, notes were made regarding implementation issues for some of the possible actions.

Total utility and GHG savings were calculated by equation 8

\[ \sum_{i=0}^{n} s_i f_i \]  

where

\[ s = \text{savings of each individual utility due to the action, in the appropriate unit for that utility}, \]
For most actions, except water and energy saving options, no utility or GHG emissions savings could be calculated. Several of the actions are likely to produce GHG reductions, most commonly Scope 3 - other indirect emissions. Examples of these are increasing the percentage of locally produced food and supplies which would decrease transportation-related GHG, and minimizing fertilizer use which would directly reduce GHG emissions (principally N₂O). Some actions have impact across multiple areas of sustainability (economic, environmental and social). Most particularly, any mitigation that involves interacting with others in the supply chain (for example, “green” purchasing policies, socially responsible investing, and community engagement) offer the potential for encouraging others to think more broadly about their impacts, which could result in additional indirect Scope 3 GHG emission reductions from those supply chain partners.

Some of the sustainability metrics have not been considered before. Actions defined for such elements were collecting and analyzing current performance data, assessing detailed options and developing specific plans or programs. Initial costs of $25,000 were estimated for each of these actions. This would reflect the time of a UC clerical specialist (using pay rates in UC, 2011). However, these could be excellent opportunities for research by students from a range of disciplines including environmental science, urban planning, engineering and applied science, and environmental health. Areas of potential research are listed in Section 4.3.4.

For most actions in the economic and social categories, work is already underway at UC. Programs exist and data is being collected by a variety of functional groups. The relevant action would be to obtain reports from the functional groups. In some cases, the existing programs may need to be expanded to
more fully address the sustainability goals. No costs were estimated for these activities, assuming it is existing work being done by the functions. Extra effort associated with these actions could be considered included in the sustainability staff responsibilities, which were estimated at $100,000, or perhaps work could be accomplished by PACES and student volunteers.

Likewise, no additional cost was estimated for actions associated with offering socially responsible investment fund options, and considering community development loan fund investments. Endowment and other investment managers for UC already perform similar work. The action would be directing that current work to include explicit analysis of sustainability impacts.

Actions where full estimates of utility savings, costs, payback and NPV could be performed were in the areas of water consumption reduction, some energy efficiency/ GHG reduction actions and renewable energy generation.

Cost and benefits for many potential energy efficiency measures could not accurately be estimated within the scope of this project. Results from energy efficiency measures retrofitted into existing buildings, such as adding reflective roofs, low-e window film, and door insulation depend on the whole building energy performance, which reflects existing roof insulation, thermal mass of walls, building orientation, and many other factors specific to the design, construction, maintenance and operation of each individual building. Other energy efficiency strategies, such as adjustment of lighting intensity levels and balancing and leak-checking air ducting, have benefits that cannot be accurately estimated as a fraction of current building energy consumption without more data than was available during the project. To accurately estimate benefits, each building must be individually surveyed and modeled using an energy model. That was beyond the scope of this project. Other potential actions that could not be estimated involve maintenance activities such as cleaning boilers, HVAC ductwork and equipment; or operational actions.
such as minimizing boiler and cooling tower blowdown. Opportunities for efficiency and savings would depend on the current maintenance and operating status for the individual equipment items. This level of detail was not considered during the project. Potential actions that could not be accurately estimated within the scope of this project are listed in Appendix J.

Renewable energy generating systems have benefits beyond their utility savings. They could be used for research purposes, and they create “renewable energy credits” which can be sold. UC has already begun burning landfill gas in the co-gen plant and sold credits to Duke Energy. Experiments with using wood chips, paper pellets and biodiesel as fuel for the co-gen plant are also underway. At present, costs and performance of renewable energy systems is evolving rapidly. Government incentives and private partnerships are often reported in descriptions of individual system installations, and would greatly determine the cost for an institution such as UC. Performance, particularly for solar PV and wind turbines, depends greatly on site climatic conditions. Finding reliable performance data for installations in Cincinnati was difficult.

A recent local example is the Cincinnati Zoo solar PV parking lot canopies that went into operation in Spring 2011. Reportedly (Cincinnati Enquirer, 2011) the system was installed by investors and leased to the Zoo who pays the investors a fixed rate for the produced electricity. An identical system was assumed for the sustainability action list, including the actual system cost. However, if UC were interested in deploying this technology, incentives and/or investors could likely be found that would significantly reduce the initial cost.

Wind power is less likely to be commercially viable. The current wind map of Ohio (EERE 2011) shows Cincinnati is in Wind Power Class 1, the lowest potential category. However, individual locations might be found where conditions are appropriate for this technology, or there could be educational or other
benefits that would outweigh cost and performance. The Cincinnati Zoo had a 2000 kW/yr turbine installed in 2010, and a 10 kW turbine was installed in Eden Park in 2006, but cost data were not available for either system. For the sustainability actions list, it was assumed that a demonstration unit could be obtained for research at minimal cost, perhaps through a power buy-back lease. It was further assumed that no utility rate savings would accrue to UC because of payback to the system installer at rates equivalent to those currently paid to Duke Energy.

Where sufficient data could be obtained, simple payback and NPV considering initial costs and utility savings were computed for these sustainability options in the same manner as for the Climate Action Plan GHG options. While many of these options would offer additional life-cycle savings such as reduced maintenance costs due to less frequent bulb changes for longer-life lighting options, insufficient information was available to compute full NPV for the options. Future work using that approach could yield more complete data and better decision-making about which options to pursue.

During this project, the only set of mitigation options that could be directly compared, GHG-based Climate Action Plan set vs. newly defined sustainability set, were water efficiency actions. The comparison is discussed in Section 4.3.4.

### 4.3.3 Optimization Model

Obviously, not all improvement actions can be undertaken simultaneously. And with practical constraints of finite financial and human resources available to implement actions, prioritization is necessary. Such problems can be solved as mathematical exercises maximizing (or minimizing) an objective function.
For demonstration purposes, a simple linear algebraic optimization model was built with a binary changing cell to represent doing (or not doing) each individual project in the water efficiency action set with the objective of maximizing NPV under a constraint of maximum capital cost of $550,000 which was the total of the set of water efficiency actions in the Climate Action Plan GHG-based list. Results are presented in Section 4.3.4.

Within the model, it would be possible to customize the constraints, the targets and other elements of the analysis to address any particular goals of the organization. Examples could include maximizing GHG reductions, minimizing capital cost, minimizing payback period, or maximizing the number of sustainability framework elements being impacted by the action. Specific targets, such as achieving a 20% GHG reduction, could also be defined by customizing the objective functions and constraints.

Additionally, more complex decision optimization models could be built for analysis through more robust software such as IBM’s ILOG CPLEX. Such programs can also handle quadratic optimization should interrelated factors be considered in the future that would have more complex relationships. Actions without numerical data (such as discrete costs and benefits), could be represented by binary variables (0-no, 1-yes), ordinal variables (such as rank ordered preferences from a focus group), or categorical variables (such as 1-low, 2-medium, 3-high) depending on the action being considered.

### 4.3.4 Comparison of Climate Action Portfolio to Sustainability Portfolio

Sustainability action planning, through analysis of total utility consumption including all forms of energy and domestic water for each building, and use of the optimization model, led to targeting a different set of
buildings than those indicated by the GHG-based Climate Action Plan. These differences are shown in Table 8.

Table 8. Comparison of Targeted Buildings for Energy Reduction Actions

<table>
<thead>
<tr>
<th>Buildings Shown in Climate Action Plan as Top Energy Consumers</th>
<th>Buildings by Total Energy Use</th>
<th>Buildings by Total Energy Use per Gross Square Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings by FY09&amp;10 avg. total energy (MMBtu)</td>
<td>FY09&amp;10 avg. total energy (MMBtu)/GSF</td>
<td></td>
</tr>
<tr>
<td>Buildings Shown in Climate Action Plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>as Top Energy Consumers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSB</td>
<td>308,451</td>
<td>Rad Safety 1.1516</td>
</tr>
<tr>
<td>CARE/Crawley</td>
<td>109,141</td>
<td>Cardiovascular 0.5072</td>
</tr>
<tr>
<td>Vontz</td>
<td>90,325</td>
<td>Eden Shop 0.4888</td>
</tr>
<tr>
<td>ERC</td>
<td>72,972</td>
<td>SRU 0.4580</td>
</tr>
<tr>
<td>CARE/Crawley</td>
<td>71,865</td>
<td>CARE/Crawley 0.4352</td>
</tr>
<tr>
<td>Vontz</td>
<td>68,321</td>
<td>Vontz 0.4249</td>
</tr>
<tr>
<td>MSB</td>
<td>54,050</td>
<td>Kettering 0.3755</td>
</tr>
<tr>
<td>Kettering</td>
<td>49,517</td>
<td>ERC 0.2844</td>
</tr>
<tr>
<td>CARE</td>
<td>41,347</td>
<td>Rieveschl 0.2731</td>
</tr>
<tr>
<td>College Rec</td>
<td>36,083</td>
<td>Alumni Center 0.2671</td>
</tr>
<tr>
<td>Calhoun Hall</td>
<td>31,644</td>
<td>Crosley 0.2527</td>
</tr>
<tr>
<td>Shoemaker</td>
<td>29,421</td>
<td>Baldwin 0.2434</td>
</tr>
<tr>
<td>Langsam</td>
<td>29,354</td>
<td>Rhodes 0.2040</td>
</tr>
<tr>
<td>Edwards</td>
<td>27,755</td>
<td>HPB 0.2036</td>
</tr>
<tr>
<td>Corbett</td>
<td>27,656</td>
<td>Dieterle 0.1951</td>
</tr>
<tr>
<td>Varsity Village</td>
<td>25,853</td>
<td>Sander 0.1890</td>
</tr>
<tr>
<td>HPB</td>
<td>24,143</td>
<td>French East 0.1885</td>
</tr>
</tbody>
</table>

Highlighting shows buildings identified through sustainability analysis that were not high interest in Climate Plan.

The Climate Action Plan list of measures also included plumbing fixture retrofits for some buildings.

Sustainability framework prioritization of buildings for water savings measures resulted in a different list of buildings than had been listed in the Climate Action Plan, as shown in Table 9.
Table 9. Comparison of Targeted Buildings for Water Reduction Actions

<table>
<thead>
<tr>
<th>Climate Plan</th>
<th>Sustainability Plan</th>
<th>Building water consumption (ccf) Average over FY09 &amp; FY10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>Building</td>
<td></td>
</tr>
<tr>
<td>Rhodes Hall</td>
<td>Cardiovascular</td>
<td>21,512</td>
</tr>
<tr>
<td>Zimmer Hall</td>
<td>Morgens</td>
<td>15,161</td>
</tr>
<tr>
<td>Kettering Kehoe &amp; IEH</td>
<td>Vontz</td>
<td>13,042</td>
</tr>
<tr>
<td>Dyer Hall</td>
<td>Daniels</td>
<td>11,923</td>
</tr>
<tr>
<td>Daniels Hall</td>
<td>Jeff Res</td>
<td>11,685</td>
</tr>
<tr>
<td>Old Chemistry</td>
<td>Siddall Dining</td>
<td>11,251</td>
</tr>
<tr>
<td>McMicken</td>
<td>Siddall</td>
<td>11,186</td>
</tr>
<tr>
<td>Proctor Hall</td>
<td>Calhoun Hall</td>
<td>9,588</td>
</tr>
<tr>
<td>Calhoun Hall</td>
<td>Dabney</td>
<td>8,797</td>
</tr>
<tr>
<td>Scioto</td>
<td>Shoemaker</td>
<td>7,994</td>
</tr>
<tr>
<td>Morgens</td>
<td>HPB</td>
<td>7,756</td>
</tr>
<tr>
<td>Health Professions Building (HPB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Langsam Library</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Highlighting shows buildings identified through sustainability analysis that were not high interest in Climate Plan

It was possible to explicitly prioritize structures for water conservation measures. The LEED (USGBC, 2009) water efficiency prerequisite “minimum indoor plumbing fixture efficiency” allows estimation of fixture flows for buildings depending on date of their construction, if actual data from fixture flow rate surveys does not exist. If buildings were substantially completed prior to 1994, it can be assumed that fixture flows are 160% of the IPC/UPC 2006 plumbing code. For buildings completed after 1994 it can be assumed at 120%. Buildings completed after 2006 should be assumed compliant with the current (2006) code. Code flows are shown in Table 10. However, fixtures currently available offer better performance than the 2006 code requires for essentially the same purchase price, so for the project, values for currently available fixtures as shown in Table 10 were used.
Applying these factors to the water consumption data for individual buildings is detailed in Appendix K.

The resulting data was then used as input to the simple optimization model (described in Section 4.3.3).

The modeling output, given in Appendix L, showed that the sustainability framework revealed a set of actions with shorter payback period, higher NPV and much higher GHG reductions, for slightly less capital outlay than the baseline GHG portfolio, as shown in Table 11.

### Table 10. Water Fixture Flow Rates

<table>
<thead>
<tr>
<th>Fixture Type</th>
<th>IPC/UPC 2006 Code</th>
<th>Currently Available Flow</th>
<th>% of current flow for post 2006 buildings</th>
<th>% of current for pre-1994 buildings</th>
<th>% of current for 1994 – 2006 era buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water closets (gallons per flush, gpf)</td>
<td>1.60</td>
<td>0.5</td>
<td>31%</td>
<td>20%</td>
<td>26%</td>
</tr>
<tr>
<td>Urinals (gpf)</td>
<td>1.00</td>
<td>0.25</td>
<td>25%</td>
<td>16%</td>
<td>21%</td>
</tr>
<tr>
<td>Showerheads (gallons per minute, gpm)</td>
<td>2.50</td>
<td>1.5</td>
<td>60%</td>
<td>38%</td>
<td>50%</td>
</tr>
<tr>
<td>Public lavatory faucets and aerators (gpm)</td>
<td>2.2</td>
<td>1.0</td>
<td>45%</td>
<td>28%</td>
<td>38%</td>
</tr>
<tr>
<td>Kitchen sink faucets (gpm)</td>
<td>2.2</td>
<td>1.0</td>
<td>45%</td>
<td>28%</td>
<td>38%</td>
</tr>
<tr>
<td>Climate Action Portfolio</td>
<td>$550,000</td>
<td>$64,545</td>
<td>9</td>
<td>$5,095</td>
<td>31</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------</td>
<td>---------</td>
<td>---</td>
<td>--------</td>
<td>----</td>
</tr>
<tr>
<td>Sustainability Portfolio</td>
<td>$539,964</td>
<td>$353,656</td>
<td>2</td>
<td>$1,980,048</td>
<td>170</td>
</tr>
</tbody>
</table>

In the project work plan, it had been envisioned that sufficient independent data could be developed regarding UC performance against the new sustainability framework elements, and costs and benefits of potential new actions. Unfortunately, the only data that could be developed for new actions was related to and based on the previous action set. So comparison results should be considered qualitative rather than quantitative.

### 4.3.4 Recommendations for Future Work Using Sustainability Framework to Prioritize Actions

Two broad classes of potential actions result from applying the sustainability framework: behavioral and technology-based measures. Behavioral means include many options listed in Appendix J, but their costs and benefits are difficult to predict. However, individual decisions result in utility consumption, so encouraging conservation must be done at the individual behavioral level. Potential behavioral actions include:
• educating students and staff around utility conservation,
  
  o particularly minimizing hot water use, which would have a double benefit of reducing
    energy used for water heating, along with reducing domestic water use;

• reinforcing education efforts through signs at key points of use such as showers, laundry, labs, and kitchens;

• incentivizing use of low temperature detergents;

• educating students and staff (particularly incoming dorm residents and students) about minimizing plug load of equipment they use or bring to campus (computers, printers, lighting);

• encouraging use of window shades to allow passive heating (in cold weather) and blocking heat gain (in hot weather)

Related technology-based actions include:

• replacing water fixtures with low-flow fixtures;

• replacing lighting lamps with CFLs, LED, induction, or other more energy efficient lamps;

• using Energy Star appliances (or encouraging their use for items brought to campus by individuals);

• installing occupancy sensors;

• applying low-e window film;

• considering additional insulation;

• HVAC system balancing, cleaning, leak-checking/repair, or other equipment efficiency improvements.

These behavioral and technology actions could all be applied in dorms. Within the buildings targeted for water efficiency improvements, six of the ten were dorms. Energy consumption by dorm (shown
previously in Table 7), showed variation between dorms whether normalized per square foot or per resident. Dorms appear to offer an interesting possibility for implementing technology and behavior based improvements for water and energy use reductions. Perhaps in an experiment could be conducted comparing actions dorm buildings of similar age and construction such as Calhoun and Siddall Halls.

Additionally, elements of the sustainability framework revealed several opportunities for research to improve understanding of sustainability implications for UC. Perhaps this work could inform the entire class of large urban research universities, or give useful information to Cincinnati local government to improve environmental and sustainability performance. Specific areas for potential research include:

- Define and reduce energy use intensity, broken down by major university operations;
- Quantify, and define options to reduce, indirect energy consumption;
- Investigate feasibility of waste to energy from biodiesel, wood chips, plastic waste, or other sources;
- Initiate programs to improve GHG modeling, especially for Scope 3 sources;
- Investigate indoor air quality, including radon levels, and options for improvement;
- Define and reduce total weight of waste by type and disposal method (solid, hazardous, radioactive, e-waste) and potential for alternate management practices such as composting or recycling;
- Investigate options for using materials that contain recycled content, and their costs and benefits;
- Investigate cost and benefit of preferred food purchasing and practices for direct university consumption, and impact of contractor participation in a preferred food program; and
- Define cost and benefit of other “green” purchasing policies, for items such as computer/electronics, cleaning products, and paper; identify the top 10 suppliers for the university and investigate their impacts and options for them to improve sustainability performance.
Relating to technology measures, using the NPV fully by including maintenance and other life-cycle cost impacts would give a more complete picture for prioritizing actions and guiding decision-making on resource allocations.

5.0 LIMITATIONS AND SIGNIFICANCE

Lack of published data regarding cost and effectiveness of potential sustainability actions – particularly for economic and social actions – prevented full use of the optimization model. Also, for many of the potential energy efficiency measures, it was not possible to accurately estimate potential savings for the explicit structures at UC due to many unknowns regarding existing building performance (e.g., what fraction of the energy currently being used is consumed by HVAC vs. lighting vs. plus load, what efficiency measures have already been implemented in each structure, and the effectiveness of such measures). A list of data elements needed to perform a more thorough analysis is presented in Appendix M.

Even with its limitations, this work will provide data to assist UC in efficiently and effectively implementing the goals of the ACUPCC Climate Commitment. Beyond GHG, a framework is suggested for achieving performance improvements in economic, broader environmental and social areas of sustainability.

Additionally, this work can inform other universities, whether they are participating in the ACUPCC program or not, as they aspire to measure and manage GHG and broader sustainability impacts. The decision model can also be applied to other organizations besides universities.
6.0 OVERALL PROJECT CONCLUSIONS AND RECOMMENDATIONS

FOR FURTHER WORK

6.1 Conclusions

The sustainability framework and use of NPV rather than just payback period led to focusing on a different set of buildings for both energy and water consumption reduction actions. Additionally, the water reduction measures prioritized by the sustainability optimization model resulted in greater NPV and shorter payback due to greater water savings, and GHG reductions that are an order of magnitude higher than the GHG-based Climate Action Plan, for slightly less capital outlay.

6.2 Recommendations for Further Work

6.2.1 Increasing Accuracy of GHG Footprint Analysis

GHG emissions from many sources, predominantly Scope 3 indirect, are not reflected in the CA-CP carbon footprint model. To more accurately estimate emissions, a life-cycle analysis approach could be used to identify the significant sources, and then the CA-CP model could be augmented to include those sources.

6.2.2 Refining Sustainability Footprint Understanding

Areas of potential future research were identified and listed in Section 4.3.4.
6.3 Improving Prioritizations for Resource Allocation

Analyzing full utility use including all forms of energy and domestic water by building, normalizing by gross square foot or occupant, and considering GHG reductions are useful tools for identifying where to focus improvement efforts.

Also, for prioritizing actions and guiding decision-making on resource allocations, using NPV fully by including maintenance and other life-cycle cost impacts would give a more complete picture than payback period alone.
7.0 REFERENCES


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