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Measuring, Managing and Visualizing Building Energy Consumption & Carbon Emissions: Benchmarking at the University of Massachusetts Amherst

Katherine McCusker

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Measuring, Managing and Visualizing
Building Energy Consumption & Carbon Emissions

Benchmarking at the University of Massachusetts Amherst
Masters Practicum Paper by
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The Green Building Committee
TABLE OF CONTENTS

Introduction

“You can’t manage what you don’t measure.” 1
Energy, CO2E emissions and Growth at UMA 2
Existing Benchmarking Initiatives 3
Benchmarking at other college campuses 7
The Value of Benchmarking for UMA 9
The Building Benchmarking Process 9
Project Description 11

Methods

A. Gathering the Data on Electricity and Steam 12
B. Converting Energy to a Common Unit 13
C. Normalizing for Weather 14
D. Normalizing for Size, Source and Site EUI 17
E. Normalizing for Occupancy 19
F. Calculations for CO2E Emissions 19
G. Visualizing these Data 19

Discussion 20

Recommendations & Next Steps 25

Conclusion 30

Works Cited 32

Appendix: Graphic Reports

Campus Maps:

Building Types
Site EUI
Total CO₂ e Emissions
CO₂ e Emissions per Person

Building EUI and Age
Building EUI Versus Carbon Emissions

Graphs of Site EUIs for all Building Type Categories
(Site EUI for FY12; Energy Consumption per Person; Site EUIs for FYs 10, 11, 12)

Administrative Buildings
Academic Buildings
Dining Halls
Residential Halls

One Building Analysis Example: Integrated Sciences Building

Benchmarking Spreadsheet Samples
List of Figures:

Figure 1. UMA Carbon Emissions and Targets
Figure 2. Correlation between Energy Consumption and Carbon Emissions
Figure 3. Building Efficiency Policy Radar Map
Figure 4. Building Efficiency Policy Map: Importance vs. Difficulty
Figure 5. Impact of Building Benchmarking Policy in the United States
Figure 6. NYC Benchmarked Offices
Figure 7. Central Heating Plant Diagram
Figure 8. Calculations to convert to a common energy unit
Figure 9. Heating Degree Days: FY10, 11, 12 Versus and Average Year
Figure 10. Impact of weather normalization on steam usage in the Integrated Sciences Building.
Figure 11. Site to Source Energy Multipliers
Figure 12. Site EUI National Averages for Building Types
Figure 13. Energy Usage Intensity (kBtu/sf) and Carbon Emissions/sf for UMA Buildings
Figure 14. Site Energy Usage Intensity for UMA Dining Halls
Figure 15. Residential Hall Energy Consumption normalized by size and occupancy
Figure 16. Integrated Sciences Building Electricity Consumption over 3 years
Figure 17. Integrated Sciences Building Total Energy Consumption over 3 years
Figure 18. Integrated Sciences Building Hourly Steam Usage
Figure 19. UMA Carbon Emissions Reduction Strategies
Introduction

“You can’t manage what you don’t measure.”

How much energy do the buildings at the University of Massachusetts Amherst (UMA) consume? The answer to this question is of interest to those tracking energy efficiency and greenhouse gas emissions, those paying utility bills, those studying building performance and perhaps to occupants of buildings themselves. Answering this question is complicated and time-consuming because data on building-level energy consumption are not collected and reported in a consistent manner, in a central place, or often not collected at all. “Benchmarking”, or measuring for the purposes of comparison, provides valuable information about building energy consumption and performance, and most importantly, carbon emissions.

UMA is committed to addressing climate change, and has established a carbon dioxide equivalent (CO₂E) emissions reduction goal. Because buildings (both their construction and operation) consume 40% of all energy, 72% of all electricity, and emit 39% of all CO₂E (USGBC) UMA’s climate change mitigation strategy must address buildings. Having good data on energy consumption at the building level will allow UMA to make better strategic decisions about where to make the necessary energy savings, and to prove that the interventions have worked. Currently UMA reports data on campus-level energy consumption, costs and carbon emissions. UMA should also have a tool to benchmark its buildings’ energy consumption and carbon emissions with interpretation designed for various campus stakeholder groups (students, the Sustainability Manager, Campus Planning, Physical Plant, Facilities Planning, etc.) to make the task of addressing building-level energy consumption easier.

The goal of this project was to establish a benchmarking methodology and tool to automate the tasks of measuring, managing and visualizing building-level energy data. This project concludes with a 3-year energy and carbon emissions comparison for all metered buildings (which amounts to 88% of the gross square footage of campus), a spreadsheet template to more easily do this work in an ongoing way, and several sample benchmarking reports. Designing a way to automate these tasks proved too difficult for the scope of this practicum project. However, it is possible to automate these processes in the near future because most of the necessary data exists on Metasys, the campus building automation software designed and installed in 2008 by Johnson Controls Inc., the company contracted by UMA to execute building energy efficiency measures. Metasys displays real-time outputs from every building utility meter and sensor (i.e.
chilled and hot water flow rates, occupancy sensors, lighting, dampers, temperature and humidity readings, etc.) With the aid of a computer programmer, the automation part of this tool could be achieved.

**Energy, CO₂E emissions and Growth at UMA**

383 buildings on the UMA campus equate to 10.7 million gross square feet (sf) accommodating 30,000 people: 84% students, 16% faculty & staff. Over the next 4-8 years UMA will grow by 17% to 12.7 million sf with an additional 4,000 students, faculty and staff. (UMass Amherst Campus Planning Division, 2012)

The Sustainability Manager, Ezra Small, recently wrote an update to the University’s Climate Action Plan, *A Vision for 2020 & Roadmap towards Carbon Neutrality*, stating,

“The Commonwealth of Massachusetts’ Executive Order 484 “Leading by Example-Clean Energy and Efficient Buildings” mandates that by 2020 all state agencies must reduce overall emissions by 40%, reduce energy consumption of their buildings by 35%, and must obtain 30% electricity from renewable energy....The particular challenge that this mandate places before us is that the University expects to add almost 2 million square feet of state-of-the-art laboratories, residence halls, and learning spaces as well as enrolling an additional 3,000 students and hiring almost 1,000 new staff over the next 4-8 years. (EPAC, 2012)

This graph illustrates the dichotomous trajectories of campus emissions and growth goals:

![UMA Carbon Emissions and Targets](image-url)
If UMA can decrease energy consumption in buildings by 35%, it will also achieve a 35% emissions reduction goal. The remaining 5% will need to come from other interventions such as renewable energy.

Benchmarking the energy consumption and carbon emissions of campus buildings is an important step in any strategy to reach energy and carbon reduction goals.

**Existing Benchmarking Initiatives**

The 2012 United Nations Conference on Sustainable Development, Rio+20, had a stated objective of doubling the global rate of energy efficiency by 2030. Addressing building energy consumption will play an important role in achieving this goal.

“Energy use by buildings offers a tremendous opportunity for governments seeking to foster clean energy technologies. Sustainability-minded policymakers should focus on three interlinked policy approaches: 1) energy policy that favors energy efficiency and distributed renewable energy sources, 2) climate policy that recognizes and internalizes the cost of carbon pollution; and 3) standards and performance criteria for the building envelope and the building components.”

(Rio+20, 2012)

The UN’s specific building initiative, titled *Driving Transformation to Energy Efficient Buildings, Policies and Actions*, outlines six policy categories which will help bring about these changes, including better building codes; energy improvement targets; awareness; incentives;
utility programs; and human and technical capacity building. The category most relevant to benchmarking is the awareness category:

“Policies that increase awareness, information and market transparency, like competitions, audits, ratings and certifications, energy performance disclosure, and public awareness campaigns.” (Rio+20, 2012)

The US Green Building Council and Johnson Controls are two of the four organizations creating this building initiative. According to the report, both “data collection and baseline development” and “building energy performance disclosure” are not properly supported by policy.

![Figure 3. Building Efficiency Policy Radar Map (Rio+20, 2012)](image-url)
In the US, progressive city mayors are taking the policy lead regarding building energy consumption. Benchmarking has become law in New York City, Washington D.C., Seattle, San Francisco, Austin and may soon be required in Boston as part of the city’s Climate Action Plan. (Boston Green Ribbon Commission, 2012)

The largest single effort is in New York City. The *Greener, Greater Buildings Plan*, specifically Local Law 84, requires public buildings over 10,000 square feet (sf), and private buildings over 50,000 sf to benchmark their energy usage. (Future reports will include other types and sizes of buildings.) Benchmarking is one of many strategies being implemented in the city to meet its goal of a 30% reduction in greenhouse gas emissions by 2017. The city expects 45% of these reductions to come from buildings. (PlaNYC, 2011)

In addition to learning which buildings are performing poorly, there is an expectation that making building energy scores public in and of itself will motivate building operators to improve energy efficiency.

“Energy reporting mandates pick up where codes leave off. While energy codes mandate increasingly stringent levels of energy efficiency in new buildings and major renovations, they don’t address existing buildings that are not otherwise being renovated, they don’t ensure that the properties are managed for efficiency, and they don’t encourage performance beyond the code minimum.” (Malin et al., 2012)
The hope is that the market will drive energy efficiency through tenants deciding to rent space from a building with lower utility bills, or the motivation of bragging rights for building owners. Building operators are often uncomfortable with these new energy disclosure laws. Not only are they seen as burdensome (Agrion, 2012), but there is concern over the fairness of the results. In Philadelphia, the president of the Building Owners and Managers Association protested against the city’s energy benchmarking reporting laws explaining that a building owner could be unfairly judged due to a tenant’s energy intensive behavior. (Malin et al., 2012)

The EPA (co-creators of the industry standard benchmarking tool and database: ENERGY STAR Portfolio Manager) claims building benchmarking has saved energy. The program database is quite large, now containing more than 250,000 buildings – an estimated 40% of the US commercial building market. (ENERGY STAR, 2012)

“Over 35,000 buildings entered complete energy data in Portfolio Manager and received ENERGY STAR scores for 2008 through 2011, which represents three years of change from a 2008 baseline. These buildings realized savings every year....Their average annual savings is 2.4%, with a total savings of 7% and score increase of 6 points over the period of analysis.” (ENERGY STAR, 2012)

Over 70% of buildings showed a reduction in energy consumption, with buildings in the retail, office and K-12 schools showing the greatest improvements.
“If all buildings in the U.S. followed a similar trend, over 18 million metric tons of CO₂E could be saved each year. Through 2020, the total savings could be approximately 25%.” (ENERGY STAR, 2012)

 laws vary about how, when and to whom these data must be disclosed. NYC’s project is precedent-setting both in scope (2,730 buildings thus far) and that the data have to be publically disclosed. In Seattle, Austin, California and Washington State, benchmarking data need only be shared during real-estate transactions (with buyers and whole building tenants). Trends are beginning to change. California will require public disclosure on commercial buildings over 50,000 sf starting in 2013 once privacy issues around the energy data are resolved. (Buonicore, 2010)

Additional initiatives that encourage energy efficiency through benchmarking include the Department of Energy’s Better Buildings Challenge, launched in December of 2011, which seeks a 20% reduction in energy use in buildings by 2020. Thus far 100 organizations representing almost 2 billion sf have signed onto the program. Architecture 2030, an organization supported by several major US cities, the AIA, and the USGBC seeks carbon neutrality by 2030. An area of Seattle calling itself the Seattle 2030 District (25 million sf of the city) responded to the Architecture 2030 initiative by seeking energy efficiencies through district heating and cooling, heat recovery and renewable power generation. Site and source EUIs of buildings within this district are benchmarked and shared publicly through dashboards. The energy targets are a bit more modest with a 50-60% reduction in energy and water by 2030. Pittsburgh and Cleveland also have 2030 districts. The 2030 challenge has not had larger success in large part because of the challenges in tracking energy data and policies against public disclosure of these data. (Melton, 2012)

Honest Buildings is an emerging online network and database of 475,000 buildings from Texas, San Francisco, DC and NYC which share their green building status and data. Unfortunately, this data is not publicly available.

**Benchmarking at other college campuses**

Currently, the only sustainability rating system for college campuses, *The Sustainability Tracking, Assessment & Rating System* or STARS, run by the Association of the Advancement of Sustainability in Higher Education does not require individual building benchmarking, only aggregated energy and carbon emissions data for the entire campus.
The industry standard benchmarking tool is ENERGY STAR Portfolio Manager, an online program developed by the EPA and DOE. Portfolio Manager allows input of annual building utility data and generates an ENERGY STAR score based on the building’s performance relative to the national average for the building type (retail, K-12 schools, food service, office building, etc.). The national median for a building type is determined by the Commercial Building Energy Consumption Survey (CBECS) database –also developed by the DOE. Unfortunately, there are not enough college and university buildings in this database to determine EUI averages for higher ed. buildings.

As a result, it is unclear how many other college campuses have benchmarked their buildings’ energy consumption. While working on a different building energy project for Facilities Planning here at UMA, I contacted several campuses that have a studio arts building similar to our own, to compare energy usage intensities. Of the handful of schools I contacted, only two were able to report to me how their studio arts buildings were performing. In some instances the building wasn’t metered, in others the meter readings weren’t accurate enough to share.

Additionally, for this practicum project, I contacted several schools inquiring as to whether they had a benchmarking program. I suspect the response I received from Peter Cooper, Manager of Sustainable Engineering & Utility Planning at the Massachusetts Institute of Technology, is indicative of the current campus situation:

“Previous attempts at benchmarking to the outside world have not been very successful. For instance DOE’s Portfolio Manager or CBECS building database are mostly about commercial office buildings. Only a very small portion of our academic buildings look like these. The Lab21 benchmarking tool seems to be much more sophisticated and useful. We have accessed it for some specific purposes but not adopted it wholesale. Even comparisons to other universities has difficulties around whether there is district energy systems serving the building or stand-alone. Variations on electricity and chilled water production can skew performance indicators by a factor of up to 3X.

We have found it most useful to benchmark against ourselves. We have over 130 buildings, which is a pretty good population. For many years we have created an annual cost distribution report which tallies annual use of each utility for each building. From that it is easy to calculate site and source energy use indices. We rank by energy intensity to prioritize our energy efficiency focus.

Recently we have constructed two excellent buildings. One is offices and classrooms for the Sloan School of Management and the other is a cancer research lab building. Their energy use models are 46% and 35% below code
respectively. We plan to use these for benchmarking our other similar buildings.”
(personal email from Peter Cooper)

**The Value of Benchmarking for UMA**

Benchmarking can help decision makers determine where UMA should begin its building-related emissions and energy reduction work because it makes clear which buildings are the most energy intensive within any given category, and which buildings have had unusual changes in energy consumption year to year (or month to month, day to day, etc.). The most useful aspect of benchmarking is that it creates a baseline from which to measure change over time, either positive or negative, as the result of occupant behavior, building programming changes, or mechanical malfunction.

**The Building Benchmarking Process**

The most common metric in benchmarking is Energy Usage Intensity (EUI), the total energy consumed (in thousand British Thermal Units, kBtus) per building divided by the gross square footage. EUI numbers can be benchmarked to demonstrate a building’s energy performance compared to similar buildings, a national average, or itself over time. The industry standard benchmarking tool is ENERGY STAR Portfolio Manager which uses the *Commercial Building Energy Consumption Survey* (CBECS) database –also developed by the DOE. The goal of the CBECS survey program was to publish results every four years, but the lastest available data are from 2003. The 2007 data were not released because they were not deemed statistically reliable, and the 2011 data were not released because of federal budget cuts to the program. (Roberts, 2011) Regardless, it is still the benchmarking standard.

The NYC benchmarking project results were graphed (Figure 6) such that buildings were ranked by EUI and color-coded based on whether the building performed worse (red) or better (green) than the national average.
CBECs does not have enough data to provide median energy scores for all commercial building types and unfortunately, higher education buildings are one such category therefore its scores are of limited value to UMA. However, UMA has the advantage of being large enough that it can benchmark against itself. There are enough buildings within most categories (administrative, residential, academic, dining, etc.) to make meaningful comparisons. UMA also has the advantage of having data on weather, occupancy, meals served in the dining halls, academic expertise on building science and architecture, a knowledgeable energy engineering staff, and graduate students eager to tackle projects which will improve the sustainability of campus. UMA has all the tools required to create meaningful internal benchmarks.
**Project Description**

All UMA buildings run on electricity and steam which together power the heating and cooling systems, mechanical ventilation systems, lights, heat water, and power the various equipment required for the mission of teaching and learning. To know how much steam and electricity is consumed per building requires building-level energy meters. Not all UMA buildings are metered. Not all metered buildings are metered completely (many have electricity meters only), and many buildings share meters. Additionally, although the raw data from these energy meters exists on Metasys, the current method of reporting energy consumption is for two staff members to take responsibility for steam and electricity separately. This has resulted in two completely distinct spreadsheets, using different building names and numbers that are challenging to combine. Chilled water data is not consistently metered so in several cases is not accounted for at all. Simply put, the data sets are incomplete, disparate and difficult to combine. Similarly, determining CO₂E emissions per building first requires an accurate measure of energy consumed per building. Calculations can then be made about emissions based on energy type.

A fellow graduate student, Zac Bloom, took a first pass at energy benchmarking at UMA using steam and electrical data from fiscal year 2011 (FY11, July 2010 – June 2011). He visualized the data and made a compelling presentation about how UMA buildings are performing. This project builds on that work, aiming to establish a methodology and ultimately a tool to automate calculating building energy usage and carbon emissions combining all energy sources, and normalizing for weather and occupancy.
Methods

A. Gathering Data on Electricity and Steam

Steam is the main energy source that runs the UMA campus. It is all generated at the Central Heating Plant (CHP) using oil and natural gas and a bit of electricity to run the steam turbines. Electricity is generated as a byproduct of the steam making process. Approximately 72% of the campus’ electricity needs are generated at CHP with the remainder purchased from the Western Massachusetts Electric Company. Figure 7 illustrates the design of the CHP:

![Figure 7. Central Heating Plant Diagram (UMA Physical Plant)](image)

Meters for both electricity and steam exist on all larger campus buildings. Raw data from the electricity meters are gathered on the “PowerLogic” server (Schneider Electric metering software). Building-level kWhs are reported by Physical Plant staff on an Excel spreadsheet, on a monthly and annual basis. The raw data from steam meters exist on Metasys, the campus wide building automation software installed in 2008. Building-level steam usage, calculated in pounds, is reported by Physical Plant staff on a separate Excel spreadsheet on a monthly and annual basis.
Since the existing steam and electricity spreadsheets use different naming and numbering conventions, the first step in this project was to create a master Excel spreadsheet using official UMA building names, numbers and gross square footage. Two tabs were created to replace the steam and electricity spreadsheets. Aggregated data (when buildings shared a meter) was divided based on square footage proportions. A third tab was created for chilled water for the eleven buildings which make use of external unmetered chillers.

The calculation to determine the energy required (again, either electricity or steam) to chill water for these buildings was to first determine ton-hours (from 3 data points on Metasys: chilled water flow-rate; chilled water supply temperature; chilled water return temperature), then convert the ton-hours into kWh or lbs of steam, depending on the type of chiller equipment used. This formula was used:

\[
\text{Ton-hours (at each 15 minute meter reading) = Flow Rate} \times 60 \times 8.34 \times (\text{Return Temperature} - \text{Supply Temperature}) / 12000
\]

\[
\text{Monthly ton-hours = Monthly average ton-hour} \times \text{number of hours in the month}
\]

A few buildings were missing from the steam spreadsheets (South College and Mullins Memorial Center), so additional Excel tabs were made for these buildings and the raw data (pounds of steam) was extracted from Metatsys.

A final combined/total energy tab is automatically populated with data from the electricity, steam and chilled water tabs.

\section*{B. Converting Energy to a Common Unit}

\begin{center}
\begin{tabular}{|c|c|}
\hline
1 lb steam & 1 ton-hour chilled water * 18 \\
\hline
1 kWh electricity & 1 ton-hour chilled water * 0.7 \\
\hline
1 lb steam & 1.194 kBTus \\
\hline
1 kWh electricity & 3.413 kBTus \\
\hline
\end{tabular}
\end{center}

Figure 8. Calculations to convert to a common energy unit

The combined/total tab pulls in the electricity, steam and chiller data and converts kWhs, lbs of steam, and ton-hours of chilled water into a common energy unit – kBTus. (Note: 8/11 external chillers use both electricity and steam, the remaining 3 are 100% electricity.)
Final Benchmarked Building Set

The result was a complete energy picture for 100 campus buildings, representing 84% of the gross square footage (8,976,233 sf /10,700,000 sf) because all larger campus buildings have been metered. The energy consumption of this set of benchmarked buildings accounts for 80% of the total campus electricity produced or purchased, and 63% of its steam production. The remainder of the electricity and steam are used in non-benchmarked buildings; non-building uses (i.e. street-lights) or is lost in transmission or not used. (See graphics, including maps in the Appendix)

C. Normalizing for Weather

The next step was to weather normalize the data. Weather normalization eliminates any benefit or penalty in energy consumption data due to weather fluctuations. Weather normalizing in this case means calculating how much energy a building would consume if the weather were normal, as determined by a statistically average year. Degree day numbers are calculated, which represent how many hours per day heating or cooling is required based on a “balance point temperature”. The baseline or balance point temperature of 60 ° was used to calculate Heating Degree Days (HDD) for this project. The choice of an appropriate balance point temperature depends on a variety of factors including how thermally resistant the building’s envelope is, the

![Figure 9. Heating Degree Days: FY10, 11, 12 Versus an Average Year](image-url)
building’s exposure to sun and wind, internal activities, people and equipment operating within the building, etc. There are calculations to determine a precise balance point temperature for an individual building, but for the purposes of this benchmarking tool, we choose an average for use for UMA as a whole.

\[
\text{HDD balance point} = 60^\circ \\
60^\circ – \text{Daily average dry bulb temperature} = \text{HDD}
\]

HDDs for this area are available from the website DegreeDays.net, using the weather data from Westfield Barnes Airport in Chicopee, MA.

The statistically average year is determined using historical weather data files collected by the Department of Energy’s (DOE) National Renewable Energy Laboratory, sometimes over a period as long as 30 years. The DOE publishes these weather files, *Typical Meteorological Year* files (the most recent being the third update or TMY3) for a variety of locations including Westfield Barnes Airport in Chicopee MA. Airports typically have more robust weather stations with wider range of meters and detail about weather. The TMY3 “normal year” is a construct of 12 statistically average months selected from the longer time period range, based on global horizontal radiation, direct normal radiation, dry bulb temperature, dew point temperature, and wind speed. (Wilcox and Marion, 2008)

Normal HDDs were calculated from this file by first converting the daily dry bulb temperatures from Celsius to Fahrenheit \((9/5 \times \text{Celsius} + 32)\) then subtracting these temperature from 60\(^\circ\), our selected balance point temperature. Monthly totals were then generated.

This benchmarking project normalized winter weather only by normalizing steam consumption for the seven heating months, October – April. (Summer weather normalization should be done in the future. It is a more complicated process because both electricity and steam are used for cooling, and humidity as well as dry bulb temperatures determine the need for cooling. Time did not allow me to do these calculations.) This approach is fairly rough and could be finessed in the future. In reality, for buildings with steam heat (over 95% of UMA buildings), steam is turned on and off at slightly different times of the year – often determined by the complaints of a building’s occupants. The schedule is not predetermined and consistent, but again, for the purposes of this project the 5-month average was used for the calculation.

Not all steam delivered to buildings is used for heating purposes. Steam is also used for cooling, hot water and specialized equipment such as autoclaves and cage washers. A baseline of steam
usage that does not account for heating must be subtracted from the monthly steam totals for the weather corrected months before the normalization calculation is applied. The baseline is typically calculated with a regression analysis - an assessment of how closely related weather and steam usage are. If the statistical correlation between HDDs and steam use was higher than 0.7 it was used as the baseline figure. If the baseline figure determined by the regression analysis was negative, or if the correlation was lower than 0.7, the 15th percentile of the yearly steam data was used as the baseline instead. The 15th percentile is essentially an estimate of steam usage during the four “shoulder months”, months when neither heating nor cooling is required and steam usage will be the lowest. Since four months represents 30% of the year, the median of those lowest four months is the 15th percentile. The steam data was weather normalized for 7 months, October – April using this technique:

Baseline corrected steam usage for building = Regression analysis figure or 15th percentile figure

Normalized Steam usage = ((Baseline corrected steam per month / HDD per month)) * HDD in a typical month TMY3

The following graph (Figure 10) demonstrates the impact of weather normalization on steam usage in one of UMA’s buildings, the Integrated Sciences Buildings. The dotted lines represent the actual steam usage in the building associated with heating whereas the solid lines represents steam the building would have used (for heating) had the weather been normal. The non-weather-normalized steam consumption is lower because the winters have been atypically warm in the three benchmarked years.
UMA collects weather data on campus and Metasys stores these data point. Going forward, Metasys could be programmed to calculate heating and cooling degree days, and eventually UMA’s own statistically average weather data.

Note, we do not normalize steam for the CO₂E emissions calculations.

D. Normalizing for Size, Source and Site EUI

To compare buildings to each other building size is normalized by dividing the total energy usage by the gross square footage. This metric is called Energy Usage Intensity, or EUI (total kBtu/gross sf) and is the standard industry benchmarking metric. Both Site EUI and Source EUIs are reported and the difference between the two is important.

The sum total of all energy used in a building, as measured by the building meters, is called site energy. Site energy is easy to calculate and is a fairly accurate portrait of energy efficiency and building performance. However site EUIs do not tell the full story, as they do not account for energy required to generate and transmit the specific energy type.

A better assessment of the environmental impact of energy use is source energy, because it includes the energy required to produce and transport the energy to the building. Delivering electricity to a building is not comparable to delivering natural gas or steam because of the relative efficiencies in how these energy sources are generated and transmitted. Electricity generation and transmission is relatively inefficient. The ratio of energy needed at the power plant to delivered electricity in a building is greater than 3:1. Some of this energy is lost in transmission – within the electricity grid itself – but most is lost in the form of heat when electricity is being generated. Steam, fuel oil and natural gas, for example, are more efficient and have a site to source ratio closer to 1:1.

The DOE publishes national average multipliers to convert site energy to source energy. These are listed in Figure 11. (Uneo and Straube, 2010) Electricity generated at the UMA CHP is roughly 75% efficient so a multiplier of 1.33 was used. (as recommended by Jason Burbank)

Source EUI is the more conventional benchmarking metric and is used by EPA’s Energy Star Portfolio Manager, LEED, the NYC building benchmarking project, and the Architecture 2030 Challenge. UMA's benchmarking tool will calculate both source

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Site to Source Multipliers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity from Grid</td>
<td>3.34</td>
</tr>
<tr>
<td>Electricity from onsite solar or wind</td>
<td>1.0</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.047</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>1.01</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>1.05</td>
</tr>
<tr>
<td>District Steam</td>
<td>1.21</td>
</tr>
<tr>
<td>District Hot Water</td>
<td>1.28</td>
</tr>
<tr>
<td>Electricity from UMA CHP</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Figure 11. Site to Source Multipliers
and site EUIs. Those interested in building performance will be interested in site EUI, those interested in carbon emissions overall energy consumption will be interested in source EUI. Those interested in improvement over time can refer to either.

Currently, the primary database building benchmarking data is CBECS which includes energy profiles for nearly 5,000 commercial buildings, provides national median EUI for a variety of building types. (EIA, 2008) Unfortunately, there are not enough college and university buildings in this database to determine EUI averages for UMA building types. One EUI is given for all college/university buildings but there is no differentiation between a cafeteria, a gym, a dorm, a science lab, etc. Figure 12 below includes the singular college/university average as well as other building categories (non-higher ed) UMA can use for benchmarking. The EPA and the DOE also sponsor the Labs21 program, which benchmarks laboratory buildings in the nation. The database is currently small. In our geographic/weather area, there are only 13 research and teaching labs, but this is as a good a starting place as any. For comparison, included in the chart are the median EUIs for buildings in the United Kingdom. The UK's Building Research Energy Conservation Support Unit (BRESCU) has established a database for university buildings. (Sapri and Muhammad, 2010) By this comparison UMA's buildings perform similarly to national

<table>
<thead>
<tr>
<th>UMA Building Types</th>
<th>UMA Averages from FY12, Site EUI (kBtu/sf)</th>
<th>National Median Site EUI (kBtu/sf)</th>
<th>Source</th>
<th>Exemplary Buildings</th>
<th>Median Site EUI for Higher Ed. Buildings in the UK (kBtu/sf)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dining Hall</td>
<td>262</td>
<td>258.3</td>
<td>Food Service (CBECS)</td>
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<td>Residential</td>
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<td>100</td>
<td>Lodging (CBECS)</td>
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<td>Library</td>
<td>69</td>
<td>92</td>
<td>Public Assembly, Library (Architecture 2030)</td>
<td>63</td>
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<td>Recreation Centers</td>
<td>74</td>
<td>93.9</td>
<td>Public Assembly (CBECS)</td>
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<td>Academic, general</td>
<td>79</td>
<td>104</td>
<td>College/University (campus-level) Architecture 2030 &amp; CBECS</td>
<td>UMA New Academic Classroom Building promises an EUI of 35 kBtus/sf</td>
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<td>Academic, lab</td>
<td>195</td>
<td>303</td>
<td>Labs21</td>
<td>Life Sciences Center at Dartmouth College = 97 kBtu/sf;</td>
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<tr>
<td>Administrative</td>
<td>113</td>
<td>90.2</td>
<td>Administrative/Prof essional Office (CBECS – Office Only Report)</td>
<td>National Renewable Energy Laboratory in Golden Colorado = 35 kBtus/sf;</td>
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<td>Administrative, health</td>
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<td>94.6</td>
<td>Outpatient and Health Care, Clinic / Other Outpatient Health (CBECS)</td>
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</tr>
</tbody>
</table>

Figure 12. Site EUI National Averages for Building Types, CBECS Database October 2006 & Labs 21 & BRESCU

* UK Targets are reported in kWh/m². 1 kBtu/sf = 3.155 kWh/m²
averages with the exceptions of administrative buildings which are consuming more energy than the national average, and labs which are consuming much less energy than our regional peers.

E. Normalizing for Occupancy

Another way to benchmark building energy usage is to normalize for occupancy, or calculate total energy consumed in the building per person. This is a particularly interesting metric when considering a dining hall, which on average will use more energy per square foot than any other type of campus building; however, its function is not comparable to others. Occupancy for dormitories, capacity for academic and administrative buildings, and meals served for the dining halls have all been added to the benchmarking database.

F. Calculations for Carbon Dioxide Equivalent Emissions

- \( \text{CO}_2 \text{E for kWh Electricity:} \)
  \[ \text{lb CO}_2 \text{E for electricity generated by the CHP} = \text{kWh} \times 0.58 \text{ lbs} \]
  \[ \text{lb CO}_2 \text{E for electricity purchased from WMECO} = \text{kWh} \times 0.83 \text{ lbs} \]

- \( \text{CO}_2 \text{E for Pounds of Steam:} \)
  \[ \text{lb CO}_2 \text{E} = \text{lb of steam} \times 0.17 \]

- Metric Tons (MT) \( \text{CO}_2 \text{E} = \frac{\text{lbs CO}_2 \text{E}}{2204.6} \)

G. Visualizing these Data

Once the building energy data was collected, the more interesting part of the project began. The following sample graphic reports can be found in the Appendix:

- Overview of Benchmarked Building Set including campus maps
- Academic Buildings
- Administrative Buildings
- Dining Halls
- Residential Halls
- One Building Analysis Example: Integrated Sciences Building
- Spreadsheet Samples

Each year there is a slightly different mix of generated electricity to purchased:
- FY10: 66% generated & 34% from WMECO
- FY11: 72% generated & 28% from WMECO
- FY12: 72% generated & 28% from WMECO
Discussion

Initial Observations:

- Steam (versus electricity) is the dominant energy source for UMA buildings.
- Electricity usage drives CO2E emissions.

Figure 13. Energy Usage Intensity (kBtu/sf) and Carbon Emissions/sf for UMA Buildings.
Benchmarking graphs make it easy to see the buildings with unusually high or low energy usage, both compared to other buildings, and when there has been a dramatic change within the building over time. For example, Berkshire Dining Hall uses lots more energy per square foot than any of the other halls. With the exception of Hampshire, all dining halls used more energy (steam) in FY 2012 than in FY 2011. (See graphic reports in the Appendix for many more examples.)

When unusual energy trends are made visible, building operators more quickly know where to investigate and which questions need to be asked. (i.e. Were the meter readings accurate; was new equipment installed in the buildings; did occupancy change; was there a malfunction of some kind?)

Normalizing for size versus size and occupancy makes a huge difference. Figure 15 shows an interesting comparison between North Dorms and Southwest dorms. When energy is compared by size (Site EUI) Southwest dorms use much more energy than the North dorms. However when compared by occupancy, they are much closer to each other because there are more students per square foot in Southwest than North.
Sub-metering is really helpful to understanding what drives energy consumption. In the Integrated Sciences Building (ISB) lights and computer/office/lab equipment account for majority of the electricity consumption. Fiscal years 2010 and 2011 are more similar than 2012, when Jason Burbank led began retro-commissioning work on the building.
Benchmarking in and of itself does nothing to improve energy efficiency. However, as an aid to help decision makers determine where building interventions need to be made, it is a powerful tool because it makes clear where the performance outliers are. These data could be used:

1. by a continuous commissioning team to determine where to begin energy work;
2. to educate the campus about energy consumption through the use of dashboards;
3. in classrooms to teach about buildings and energy – the campus as a lab concept;
4. by building operators to learn how buildings are performing on a monthly, daily or hourly basis.

Figure 17. Integrated Sciences Building Total Energy Consumption over 3 years.
In general, UMA is not performing much worse than the national average for most building types, but there is certainly great room for improvement. One of the reasons attention hasn’t been given to improving the performance of existing buildings is the Operations and Maintenance staff is undersized. De-facto, their management style is reactionary, or complaint-driven. None has time to take a proactive role in analyzing building performance. Adding this type of investigative work to the job descriptions of operations staff, or better yet hiring a Continuous Commissioning Team is an important next step. This benchmarking tool will save some time in the diagnostic process.
Recommendations & Next Steps

The following are recommendations to both improve the benchmarking tool itself and the energy efficiency of campus buildings:

A. Individually meter all residence halls.

There is great potential for energy savings and education about energy consumption and carbon emission via “green games” or other types of energy savings competitions. Other campuses have successfully demonstrated the positive impact of green games in residential hall energy consumption. The campus Sustainability Manager and the Eco-Reps would like to launch such an initiative at UMA but cannot until all the residential halls are individually metered. Currently the majority of the dorms (30) use group and/or virtual electricity meters. Nearly half as many use group steam meters.

B. Add condensate meters for steam.

The current UMA steam meters are differential pressure meters, using orifice plates to measure steam flow through pressure changes. This type of meter is notoriously inaccurate, especially during low-flow time times such as the summer. Condensate meters, which measure a liquid, are much more accurate. (Jason Burbank)

C. Finalize and Automate the benchmarking tool:

1. As an interim step, modify Metasys and the campus utility spreadsheets in the following ways:
   - Use official building names and numbers throughout.
   - Add Mullins Center and South College to Steam spreadsheet.
   - Create a spreadsheet for Chiller Data for buildings with external chillers. Programming Metasys to calculate monthly ton-hours of chilled water.
   - Consistently report chilled water flow-rates. Most of Metasys data is reported in 15 minute intervals but there are several exceptions in the chilled water data points – i.e. Conte Polymer Research Center reports chilled water flow and supply temperatures in 1 hour intervals, but return temperature in 15 minute intervals. Mullins Memorial Center chilled water flow is 30 minutes. All chilled water data points in the Engineering and Computer Science Center are 30 minute intervals.
2. **Weather normalize energy data for summer or cooling months.**

3. **Determine a consistent emissions factor for calculating CO2E Emissions.**

   The CO2E emissions total for these 100 benchmarked buildings is higher than the figure reported in the Climate Action Plan (CAP) report. For fiscal year 2012 the CAP reported 126,947 MT whereas this tool calculated 160,831 MT and excluded emissions from campus vehicles. The CAP figure comes from the Campus Carbon Calculator created by Clean Air Cool Plant, which uses emissions factors based on our fuel import region. The carbon emissions factors used in this benchmarking tool were provided to me by a staff member in the Environmental Health and Safety Department. He used ISO NEPOOL factor numbers to derive a more accurate calculation for our campus. Unfortunately this staff member has recently left the University, and I was not able to learn which emissions factors the Clean Air Cool Planet calculator used or how he derived the campus-specific factors.

   Additionally, UMA hires a consulting agency (Berkshire Environmental) to report emissions as required by the US EPA and the Mass DEP. The EPA report uses emission factors from 40 CFR 98, and the Mass DEP report uses factors from the Climate Registry, and they often differ from each other and from other campus calculations. For example, the Mass DEP report for FY2012 was 110,157 MT.

   Clearly one issue is that emissions factors differ from calculator to calculator. Another issue is that what gets reported for campus-wide emissions are derived from total fuels purchased to operate the CHP versus end use energy – the steam and electricity consumed/metered in the buildings. UMA should determine the most accurate methods and emissions factors and use them consistently.

4. **Compare ENERGY STAR Portfolio Manager Source EUIs with the UMA benchmarking tool’s Source EUIs.**

   ENERGY STAR Portfolio Manager does not have a pull-down menu option for district electricity (as they do with district steam). When we have used Portfolio Manager thus far we have entered all electricity consumption per building as if it
were all purchased from WMECO, so we have been given falsely high source EUI figures. An ENERGY STAR support person offered this instruction in an email correspondence:

“If you are benchmarking a facility that has a combined heat and power plant, you are required to enter the input fuel into Portfolio Manager. That is, if you have a plant that takes natural gas as an input to produce steam and electricity, you would enter a meter to quantify all natural gas inputs to the CHP. You do not need to report the outputs (steam and electricity). When you enter the natural gas, you will be credited for the efficiency of the CHP because your plant will produce electricity and steam with greater efficiency than they could otherwise be purchased.” (12/11/2012)

As a next step, data from a few benchmarked buildings could be entered into Portfolio Manager in this alternative way to see how close the EUI figures are. In addition, if UMA pursues LEED certification for any of its existing buildings, any differences will be important to understand as Portfolio Manager is the benchmarking tool used by LEED.

5. **Add water consumption to the benchmarking tool.**

UMA collects data on water consumption per building. This data set should be added to the benchmarking tool.

6. **Automate the benchmarking process by using Metasys and some other database program, perhaps Tririga the campus facility asset management software which contains other important data sets such as capacity and space type allocations.**

The benchmarking approach taken in this project should be seen as a first-step, not a final product. This approach is labor intensive with great possibilities for human error. A more accurate and efficient method for benchmarking energy usage and carbon emissions would be to automate the process with a computer database program. Currently Metasys collects granular data (at 15 minute intervals) on a variety of data points including energy, occupancy, weather, water and building mechanical systems. This granular data would allow the benchmarking tool to illustrate what’s happening within a building on weekly, daily, or hourly, and 15 minute interval basis. It is a robust program with great potential that is poorly programmed and underutilized at UMA. Since its implementation in 2008, it has
been archiving data on all metered buildings. Metasys, not campus utility spreadsheets should be the source of energy data. If Metasys is paired with another database program such as Tririga, which would add data sets on occupancy, capacity, sf percentages within a building which are office space/classroom/lab, number of meals served in the dining halls, etc., the benchmarking tool would be very robust.

D. **Set EUI targets for new construction.**

It’s always better to design efficiency into a building than retrofit an existing design. UMA is planning 2 million square feet of new building construction in the next decade. The EUI goals for this new construction should align with the best of design and construction practices. The National Renewable Energy Laboratory office in Golden Colorado has been operating for two years with a site EUI of 35 (and an EUI of 25 without the data center). The new Academic Classroom Building being built at UMA has a targete site EUI of 35. There are other exemplary buildings in the world from which UMA could establish targets based on building function. (See Figure 12)

E. **Through commissioning and retro-fitting, find a 35% reduction in energy consumption (from 2002) by 2020 (the EO484 mandate).**

UMA should use this benchmarking tool to document its own improvements in energy efficiency over time. To find a savings of 35% in energy consumption and reduce carbon emissions by 40% UMA will need to address the existing building stock strategically. Retro-commissioning (returning a building to its original performance intention or “re-tuning” the building), retro-fitting (making modification to the original design of the building), and behavioral change strategies will be required to meet these goals. UMA should establish a Continuous Commissioning Team of qualified building scientists and engineers to improve and maintain campus buildings from an energy point of view. The Green Building Committee wrote a proposal to do just this basing the projected savings on a Lawrence Berkeley National Laboratory study which determined a 16% median energy savings per building with retro-commissioning. The study also showed that buildings stop performing optimally after about 5 years – thus the need for continuously commissioning buildings. In addition, the Green Building Committee’s commissioning proposal drew on the results of a retro-commissioning “light” pilot project (not all typical retro-commissioning tasks were performed), which proved this work pays off. The pilot project was conducted for 6 months on the Studio Arts Building and the Integrated
Sciences Building and resulted in a savings $76,770 total, 16% energy savings in the ISB, 6% in the SAB. (Contact the Green Building committee for a copy of the report.)

The impact of retro-fitting campus buildings has also been studied at UMA. Dr. Benjamin Weil led an independent study which analyzed Holdsworth Hall from an energy and occupant comfort point of view. A set of recommendations were proposed which would have a dramatic impact on the energy efficiency of the building, reducing its site EUI from 115 to 37! One key finding was if such electricity reductions were multiplied across all buildings of a similar type it would be possible to dramatically decrease if not eliminate the need to purchase electricity from WMECO. The CHP currently produces about 72% of the electricity used on campus, at a much cheaper rate than that purchased from WMECO. The financial benefit of decreased electricity consumption is significant. “...a 21% energy savings would gain a 46% financial savings. A goal of living within the energy means of the CHP should be seriously considered.” (The Holdsworth Report is available from the Green Building Committee)
Conclusion

"Global warming happens just slowly enough that political systems have been able to ignore it. The distress signal is emitted at a frequency that scientists can hear quite clearly, but is seemingly just beyond the reach of most politicians." (Remnick, 2012)

The Green Building Committee has identified four key strategies to meet carbon emissions reduction goals:

![Figure 19. UMA Carbon Emissions Reduction Strategies (Lawson Wulson)](image)

These strategies will come with a hefty price tag, which will engender criticism. Some will ask if UMA would be doing more than its fair share – working harder, and spending more money to achieve these energy and emissions goals than its peers. Some will be concerned that spending resources to meet the state emissions mandate would come at the expense of supporting UMA’s educational mission, i.e. spending the financial resources directly on teaching and learning, which would risk UMA’s competitive edge in the higher education market.

Fortunately, energy efficiency improvements and CO₂E reductions will also save money! To properly account for costs and benefits of energy efficiency work requires a shift in thinking about payback periods and the social/environmental values of UMA’s investments. Traditionally
projects at UMA are funded if they can show a 7-year simple payback period. This approach is too simplistic because it doesn’t compare the benefits of the work to the cost of the status-quo, nor does it allow a proper comparison between current university investments and energy efficiency investments.

When UMA is ready to seriously address unnecessary energy consumption in its buildings, an automated benchmarking tool will be very valuable.
Works Cited


Ueno, Kohta, Straube, John; *Understanding Primary/Source and Site Energy; Building Science Digests, August 10, 2010*


### Profile of Benchmarked Buildings:

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<th>Total</th>
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<td>Administration</td>
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</table>

**Gross Square Footage:**
8,976,233 (of 10.7 million, 84%)

**Years Benchmarked:**
- Fiscal Years: 2010, 2011, 2012 (Fiscal Year = July-June)

**Building Types:**
- Acad
- Acad, Library
- Acad, Lab
- Admin
- Admin, Health
- Dining
- Gym
- Res

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, i-Tree Environmental, MapInfo, CoreLogic, ITC, Intergraph, BenCmark, and the GSS user community.
CO2E EMISSIONS PER PERSON

Facilities - EPAC
FY12 Total CO2 EMT person

0.34 - 0.79
0.80 - 1.35
1.36 - 1.91
1.92 - 2.37
2.38 - 3.07
3.08 - 4.38
4.39 - 7.43
7.44 - 11.69

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community
## Energy Consumption of Administrative Buildings

### Site EUI, FYs 2010-2012

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<td>Whitmore Hall (1967)</td>
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</table>

**Site EUI Elec.**

- **UHS (FY12)** = 83 kBtus/sf
- **UMA Average for Administrative Buildings** = 113 kBtus/sf
- **National Average for Health Services** = 94.6 kBtus/sf
- **UMA Average for Gyms (FY12)** = 74 kBtus/sf
- **National Average for Public Assembly** = 93.9 kBtus/sf
- **National Average for Offices** = 90.2 kBtus/sf
- **UMA Average for Administrative Buildings** = 113 kBtus/sf
### Energy Consumption of Academic Buildings

#### Site EUI, Fiscal Year 2012

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<th>Library</th>
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<tr>
<td>Conte Polymer (1985)</td>
<td></td>
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<tr>
<td>Engineering Lab I (2004)</td>
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<tr>
<td>Morrill III (1962)</td>
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<tr>
<td>Geonmian Lab (1958)</td>
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<tr>
<td>DuBois Library (1972)</td>
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</tbody>
</table>

#### Energy Consumption of Academic Buildings per Person, Fiscal Year 2012

<table>
<thead>
<tr>
<th>Building</th>
<th>kBtu/person</th>
<th>Non-lab</th>
<th>Lab</th>
<th>Library</th>
<th>FY12 kBtu/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>DuBois Library (1972)</td>
<td>10000</td>
<td></td>
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<tr>
<td>Skinner Hall (1949)</td>
<td>20000</td>
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<tr>
<td>South College (1985)</td>
<td>30000</td>
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<tr>
<td>Mills House (1948)</td>
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<tr>
<td>Arnold House (1954)</td>
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<td>Draper Hall (1947)</td>
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<td>MacLean Hall (1957)</td>
<td>70000</td>
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<td>Morrill Hall (1950)</td>
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<td>Bartlett Hall (1960)</td>
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<tr>
<td>Stockbridge Hall (1932)</td>
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<td>Fernald Hall (1910)</td>
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<td>Marcus Hall (1946)</td>
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<td>Flint Laboratory (1932)</td>
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<td>Engineering Lab I (2004)</td>
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<td>DuBois Library (1972)</td>
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**Measuring, Managing and Visualizing Building Energy Consumption & Carbon Emissions**

**Benchmarking at the University of Massachusetts Amherst**

Katherine McCusker
Energy Consumption of Academic (non-lab) Buildings

Site EUI, Fiscal Year 2012

UMA Average for FY12 = 79 kBtus/sf
National Average = 104 kBtus/sf
Energy Consumption of Academic Lab Buildings
Site EUI for FYs 10-12

- UMA Average FY12 = 195 kBtus/sf
- Regional Average = 303 kBtus/sf

How to read these results

User not logged in. (Log in)

Benchmarked Lab Buildings from UMA Climate Zone, Labs21
DINING HALLS

Energy Consumption of Dining Halls, Fiscal Year 2012

Dining Halls

Energy Consumption of Dining Halls, Fiscal Year 2010-2012

(U.S. Average = 262 kBTUs/sf)

Energy Consumption of Dining Halls per Meals Served

(UMA Average (FY12) = 258.3 kBtus/sf)

UMA Average (FY12) = 262 kBtus/sf

National Average = 258.3 kBtus/sf
Residential Halls Energy Consumption
Site EUI Fiscal Year 2012

Central
North
Northeast
Orchard Hill
Southwest
Sylvan
FY12 Site EUI Elec.
FY12 Site EUI Steam

National Average = 100 kBtu/sf
UMA Average (FY12) = 79 kBtu/sf
Measuring, Managing and Visualizing Building Energy Consumption & Carbon Emissions
BENCHMARKING AT THE UNIVERSITY OF MASSACHUSETTS AMHERST
Katherine McCusker

Residential Halls Energy Consumption per Person Fiscal Year 2012

- McNamara House (1971)
- Brown House (1971)
- Cashin House (2005)
- Cane House (1940)
- Washington House (1966)
- Pierpont House (1968)
- Adams, John Quincy (1966)
- Adams, John House (1966)
- Coolidge House (1956)
- Patterson House (1967)
- Kennedy House (1966)
- Prince House (1967)
- Crampton House (1967)
- Moore House (1968)
- MacKimmie House (1967)
- Thoreau House (1966)
- Melville House (1966)
- James House (1966)
- Emerson House (1966)
- Webster House (1965)
- Dickinson House (1965)
- Field House (1928)
- Grayson House (1965)
- Mary Lyon House (1959)
- Lewis House (1940)
- Hamlin House (1949)
- Crabtree House (1953)
- Dwight House (1959)
- Johnson House (1960)
- Thatcher House (1955)
- Leach House (1953)
- Knowlton House (1949)
- Van Meter House (1957)
- Baker House (1952)
- Chadbourne House (1947)
- Brooks House (1949)
- Wheeler House (1958)
- Gorman House (1963)
- Greenough House (1946)
- Battenfield House (1930)
- Brett House (1963)
Residential Buildings

Central Dorms, SITE EUI FYs 10-12

UMA Average (FY12) = 79 kBTU/sf
RESIDENTIAL BUILDINGS

North & Northeast Dorms, Site EUI FYs 10-12

Orchard Hill & Sylvan Dorms, Site EUIs FYs 10-12

UMA Average (FY12) = 79 kBtus/sf
Residential Buildings

Southwest Dorms, Site EUI FYs 10-12

- Adams, John (1966) FY10
- Adams, John (1966) FY11
- Adams, John (1966) FY12
- Adams, John Quincy (1966) FY10
- Adams, John Quincy (1966) FY11
- Adams, John Quincy (1966) FY12
- Cance (1940) FY10
- Cance (1940) FY11
- Cance (1940) FY12
- Coolidge (1966) FY10
- Coolidge (1966) FY11
- Coolidge (1966) FY12
- Crampton (1967) FY10
- Crampton (1967) FY11
- Crampton (1967) FY12
- Emerson (1966) FY10
- Emerson (1966) FY11
- Emerson (1966) FY12
- James (1966) FY10
- James (1966) FY11
- James (1966) FY12
- Kennedy (1966) FY10
- Kennedy (1966) FY11
- Kennedy (1966) FY12
- MackKimmie (1967) FY10
- MackKimmie (1967) FY11
- Melville (1966) FY10
- Melville (1966) FY11
- Melville (1966) FY12
- Moore (1968) FY10
- Moore (1968) FY11
- Moore (1968) FY12
- Patterson (1967) FY10
- Patterson (1967) FY11
- Patterson (1967) FY12
- Pierce (1968) FY10
- Pierce (1968) FY11
- Pierce (1968) FY12
- Prince (1967) FY10
- Prince (1967) FY11
- Prince (1967) FY12
- Thoreau (1966) FY10
- Thoreau (1966) FY11
- Thoreau (1966) FY12
- Washington (1966) FY10
- Washington (1966) FY11
- Washington (1966) FY12

UMA Average (FY12) = 79 kBtus/sf
INTTEGRATED SCIENCES BUILDING
ENERGY PROFILE OF ONE CAMPUS BUILDING

BUILDING PROFILE:

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Integrated Sciences Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Number</td>
<td>676</td>
</tr>
<tr>
<td>Building Type</td>
<td>Academic, Lab</td>
</tr>
<tr>
<td>Gross Square Footage</td>
<td>188,332</td>
</tr>
<tr>
<td>Capacity</td>
<td>1,761</td>
</tr>
<tr>
<td>Year Acquired</td>
<td>2008</td>
</tr>
<tr>
<td>Period of Analysis</td>
<td>FY 2010 - 2012</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Site EUI</th>
<th>Average Source EUI</th>
<th>Total kBtus</th>
<th>Average kBtu/Person</th>
<th>Total MT CO2E Emissions</th>
<th>Average CO2E/Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY10</td>
<td>258</td>
<td>381</td>
<td>48,585,654</td>
<td>27,598</td>
<td>9,449</td>
</tr>
<tr>
<td>FY11</td>
<td>268</td>
<td>397</td>
<td>50,462,903</td>
<td>28,656</td>
<td>10,148</td>
</tr>
<tr>
<td>FY12</td>
<td>254</td>
<td>375</td>
<td>47,782,372</td>
<td>27,134</td>
<td>8,939</td>
</tr>
</tbody>
</table>


ISB Annual Energy Usage

FY10 kBtu
FY11 kBtu
FY12 kBtu
FY12 kBtu - non normalized
Integrated Sciences Building
Energy Profile of One Campus Building

Electricity vs Steam Use FYs 10-12

ISB Annual Electricity Usage

ISB Electricity Usage, Lights & Receptacles vs Mechanical System vs Chiller
Hourly Steam Usage, Weather Normalized, in the ISB for the first 3 weeks in December

ISB Electric Use (6 mo. period)

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
<th>Costs*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>2,258,203</td>
<td>$156,673</td>
</tr>
<tr>
<td>FY12</td>
<td>1,884,299</td>
<td>$130,796</td>
</tr>
<tr>
<td>Diff.</td>
<td>373,904</td>
<td>$25,877</td>
</tr>
</tbody>
</table>

Yearly projected savings for FY2012= $51,754

*using blended electrical rates from FY2011

ISB Steam Use (6 mo. period)

<table>
<thead>
<tr>
<th></th>
<th>lbs</th>
<th>Costs*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>17,810,606</td>
<td>$249,348</td>
</tr>
<tr>
<td>FY12</td>
<td>14,833,577</td>
<td>$207,530</td>
</tr>
<tr>
<td>Diff.</td>
<td>2,977,029</td>
<td>$41,818</td>
</tr>
</tbody>
</table>

Yearly projected savings for FY2012= $83,637

*using consistent kWh rate

ISB Electric Chiller (6 mo. period)

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
<th>Costs*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY11</td>
<td>399,219</td>
<td>$26,269</td>
</tr>
<tr>
<td>FY12</td>
<td>362,050</td>
<td>$23,823</td>
</tr>
<tr>
<td>Diff.</td>
<td>37,169</td>
<td>$2,446</td>
</tr>
</tbody>
</table>

Yearly projected savings for FY2012= $4,891

*using consistent kWh rate

### Results of Retrocommissioning Project on the ISB, July - December 2011

**ISB Energy Costs & Anticipated Savings:**

<table>
<thead>
<tr>
<th>Costs FY11</th>
<th>$869,951</th>
<th>$140,282</th>
<th>16.13%</th>
</tr>
</thead>
<tbody>
<tr>
<td>kBtu FY11</td>
<td>61,945,362</td>
<td>4,969,505</td>
<td>16.04%</td>
</tr>
</tbody>
</table>

The first round of energy savings at the ISB were obtained by:

- using teaching lab occupancy schedules
- optimizing static pressure setpoints for all building supply and exhaust/return fans
- optimizing air handler discharge air setpoints to dehumidify only when required
- reducing fume hood exhaust levels nights and weekends (still subject to room occupancy sensors)
- reducing static pressures except when labs are occupied
- drastically reducing office wing fan speeds overnight to save fan horsepower, but maintained required building pressure and humidity levels

The bulk of savings were accrued from reduced fan horsepower, particularly during unoccupied periods, with chilled water and steam savings also arising from optimized supply air temperature setpoints.

Significant further savings can be achieved by automating static pressure optimization, demand controlled ventilation in the office wing, making use of lab shutdown mode during extended unoccupied times, and improved programming of heat wheel control as well as improved lighting control.

Although steam savings this year have been large in the winter months, these are predominantly due to much warmer weather this year compared to last. Only the steam savings appearing in the summer and fall, due to reduced reheat requirements, are attributed to this retro-commissioning effort.
<table>
<thead>
<tr>
<th>Building Name</th>
<th>Bldg.</th>
<th>FY10 % Electricity</th>
<th>FY10 kBtu/person</th>
<th>FY10 % Steam</th>
<th>FY12 kBtu/person</th>
<th>FY12 Site EUI CO2E/sf</th>
<th>FY12 kBtu/person</th>
<th>FY12 Site EUI CO2E/sf</th>
<th>FY12 % Steam</th>
<th>FY12 kBtu/person</th>
<th>FY12 Site EUI CO2E/sf</th>
<th>FY12 kBtu/person</th>
<th>FY12 Site EUI CO2E/sf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grayson House (1965)</td>
<td>330 Res78,214</td>
<td>1965 33% 78% 70 16,184 96 857 2.53 0.0110</td>
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<tr>
<td>Gorman House (1963)</td>
<td>294 Res66,335</td>
<td>1963 32% 74% 63 14,691 96 620 1.92 0.0093</td>
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<tr>
<td>Field House (1926)</td>
<td>332 Res78,214</td>
<td>1926 33% 77% 78 17,894 105 804 2.37 0.0103</td>
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<tr>
<td>Dickinson House (1965)</td>
<td>331 Res78,214</td>
<td>1965 33% 77% 56 13,309 76 609 1.84 0.0078</td>
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<tr>
<td>Crampton House (1967)</td>
<td>380 Res52,619</td>
<td>1967 14% 86% 125 27,763 162 949 2.70 0.0121</td>
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<tr>
<td>Crabtree House (1953)</td>
<td>12 Res33,273</td>
<td>1953 23% 77% 71 16,450 96 305 2.12 0.0092</td>
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<tr>
<td>Coolidge House (1966)</td>
<td>353 Res147,423</td>
<td>1966 21% 79% 73 19,290 98 1,422 2.55 0.0096</td>
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<tr>
<td>Butterfield House (1930)</td>
<td>5 Res46,190</td>
<td>1930 19% 81% 86 28,303 110 465 3.49 0.0101</td>
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<tr>
<td>Mullins Memorial Center (1993)</td>
<td>613 Admin 264,654</td>
<td>1993 33% 67% 158 81,371 224 6,882 13.36 0.0260</td>
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<tr>
<td>University Health Center (1973)</td>
<td>418</td>
<td>1973 33% 67% 72 18,972 96 1,267 2.27 0.0086</td>
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<tr>
<td>Studio Arts Building (2008)</td>
<td>677 Acad, lab 52,881</td>
<td>2008 53% 40% 89 12,569 138 942 2.51 0.0178</td>
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<tr>
<td>Morrill IV (1966)</td>
<td>347 Acad, lab 123,247</td>
<td>1966 53% 44% 176 28,638 272 4,281 5.66 0.0347</td>
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<tr>
<td>Lederle Grad Research (1973)</td>
<td>502 Acad, lab 506,147</td>
<td>1973 34% 66% 172 28,296 244 13,491 4.39 0.0267</td>
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<tr>
<td>Hasbrouck Lab, Add.Only (1963)</td>
<td>318 Acad, lab 72,825</td>
<td>1963 19% 87% 219 14,549 291 1,940 1.77 0.0266</td>
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<tr>
<td>Flint Laboratory (1912)</td>
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<td>Academic Year</td>
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<td>Carbon Emissions (Metric Tons)</td>
<td>Year</td>
<td>Energy Use (kWh)</td>
<td>Carbon Emissions (lb CO2)</td>
<td>Carbon Emissions (Metric Tons)</td>
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## Benchmarking Spreadsheet: FY12 Data

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