1907–2007
CENTENNIAL

East Carolina University

Comprehensive Master Plan

Energy & Greenhouse Gas Emissions Report

Final Report

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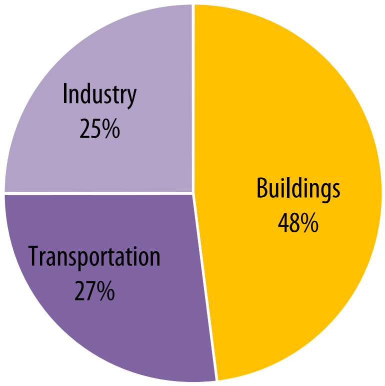
1. INTRODUCTION

The Comprehensive Master Plan for East Carolina University provides a future vision for both East Carolina University's Main Campus and the Health Sciences Campus, translating the principles and key themes developed during the master planning process into a graphical representation. Both short and long-term opportunities for the continued growth and development of the University are represented in the plan. The master planning process tested projected program and space needs for the Main and Health Sciences Campuses in order to best achieve the vision of the Master Plan. This program is an estimate of future needs based on recognized benchmarking of similar institutions and decisions made by the University as to specific possible needs in the future. While it is impossible to predict the exact needs of the University, this program sets a reasonable and flexible framework in which East Carolina University can grow for the foreseeable future. The master plan also describes the demolition and renovation candidates envisioned within the framework.

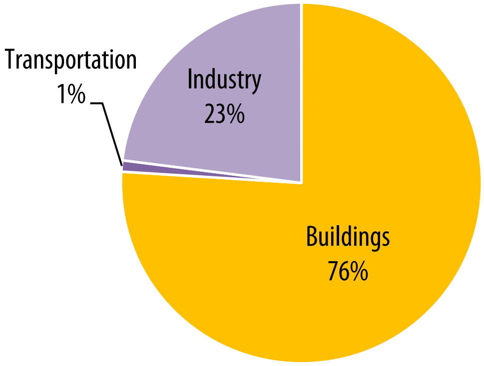
East Carolina University is committed to developing a sustainable campus, and to contributing to an enhanced environment for the City of Greenville and the region. Signed by Chancellor Ballard in 2006, the ECU Safety and Environmental Policy Statement establishes the University's commitment to pursuing environmental sustainable design initiatives for campus activities and developments. The Campus Master Plan emphasizes sustainability considerations that will inform future implementation, playing an important role in the development and improvement of East Carolina University's campus. This Energy and Greenhouse Gas (GHG) Emissions Report accompanies the master plan, showing how, by embracing energy conservation measures, the campus can grow as envisioned in the master plan, while at the same time can reduce its carbon footprint.

By the year 2030, the East Carolina University (ECU) campuses will grow with the addition of over 2.6 million square feet of building. This growth could potentially increase the amount of greenhouse gas emissions produced by the operation of campus buildings. Buildings are the single largest contributor to global warming. 48% of the US's energy use is associated with the energy to construct and operate buildings, and building operations account for 76% of the US's electricity consumption. (from "THE BUILDING SECTOR: A Hidden Culprit", www.architecture2030.org)

US Energy Consumption



US Electricity Consumption



By embracing sustainable design strategies, it is possible for the University to grow while reducing its greenhouse gas emissions. This report estimates the greenhouse gas emissions associated with the existing main and health science campuses, predicts the energy use of the proposed development based on current campus building standards, and demonstrates how sustainable design strategies applied to all new development, as well as how sustainable renovation, retrofit, and improvements to the existing building stock can significantly reduce the carbon footprint of ECU.

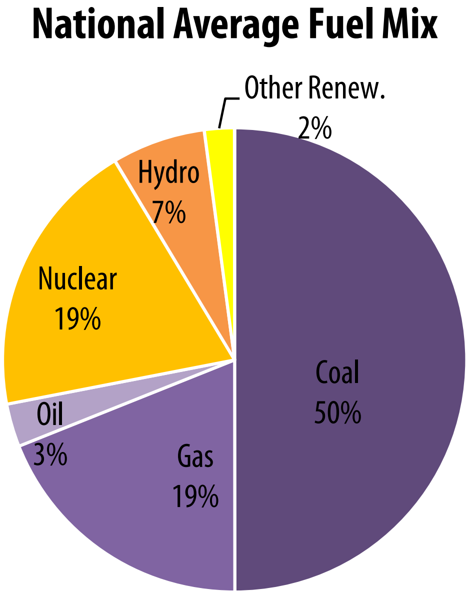
2. MEASURING CARBON

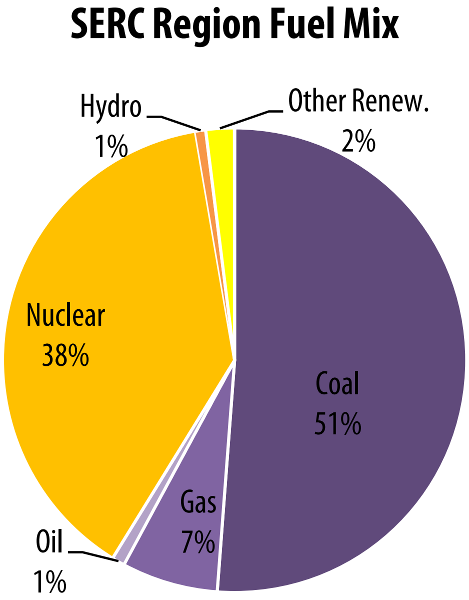
Greenhouse Gas Inventories

The World Resources Institute and the World Business Council on Sustainable Development developed a standardized protocol to determine greenhouse gas inventories, identifying three potential "scopes" within this inventory. A total greenhouse gas inventory for a campus includes emissions from direct sources such as on-campus energy production (Scope 1 emissions), purchased energy from off-site sources (Scope 2 emissions), and from indirect sources such as the emissions associated with transportation on campus and commuting to and from the campus (Scope 3 emissions). Scope 1 and 2 emissions are largely associated with the energy to operate campus buildings, while Scope 3 pertains to campus transportation approaches. ECU's Scope 1 emissions largely consist of the emissions from its central steam plants. Scope 2 emissions are comprised of the campus' purchased electricity – both the electricity to power the campus and to produce chilled water at central chilled water plants. This report will focus on the Scope 1 & 2 emissions of the campus, both estimating those emissions and identifying means of reducing them.

Energy Sources

ECU's energy sources consist of purchased electricity, natural gas, and fuel oil. These fuels are used directly in campus buildings, as well as in the campus central plants to produce chilled water and steam. Purchased electricity comes from the SERC Virginia/Carolina electrical grid. The national electric grid is divided into regions, and the fuel mix used to produce electricity varies by region. Within the SERC Virginia/Carolina region, coal is the largest fuel source, accounting for over 51.2% of the fuel mix. The national average fuel mix uses 49.9% coal. The large reliance on nuclear energy to produce electricity results in a lower rate of GHG emissions per kWh of electricity in the SERC region compared to the National Average.





Chilled Water

Main Campus & Athletic Facilities

The main campus chilled water system consists of two chilled water generation plants, capable of generating 7,050 tons of cooling. The generation system includes seven electric motor-driven water-cooled chillers, seven cooling towers, chilled water pumps, and approximately 3,500 linear feet of direct buried chilled water supply and return piping. The main chilled water plant on the north side of main campus, CCP-1 is built into the Science and Technology Classroom Building while the chilled water plant for the athletic complex on the south end of main campus, CCP-2 is in Minges Coliseum. The chilled water generation equipment is approximately seven years old.

Health Sciences Campus

The health science chilled water system consists of a single chilled water generation plant capable of generating 6,000 tons of cooling. The generation system includes seven electric motor-driven water-cooled chillers (six active), six cooling towers, chilled water pumps, and approximately 3,100 linear feet of direct buried chilled water supply and return piping. A portion of the chilled water piping resides in a utility tunnel approximately 550 feet long. The chilled water plant shares the same building as the steam plant and facilities personnel for the ECU's Health Science Campus. The chilled water generation equipment ranges from 4 to 13 years old.

Steam

Main Campus

The main campus steam system consists of a single boiler plant capable of generating 265,000 lbs/hr (PPH) of steam and distributing at a pressure of 100 psig. The generation system includes four water tube boilers, a deaerator, condensate tank, feed water pumps, water softening equipment, chemical treatment equipment, a plant master control system, and associated piping to distribute steam to the campus. The system includes a distribution network of approximately 57,000 linear feet including steam distribution and condensate return piping varying in sizes throughout campus. The campus is served by a network of piping residing in tunnels, half shell trenches, and direct buried casings. The boilers and auxiliary equipment ranges from 7 to 44 years old.

Health Sciences Campus

The health science steam generation system consists of a single boiler plant connected to the central chilled water plant. It is capable of generating 50,000 lbs/hr (PPH) of steam at a pressure of 100 psig. The generation system includes two firetube boilers, a deaerator, condensate tank, feed water pumps, water softening equipment, chemical treatment equipment, and associated piping to distribute steam to the campus. The system includes a network of direct buried and trench piping totaling 6,800 linear feet, including a utility tunnel approximately 1,700 feet long. The steam generation equipment ranges from 5 to 15 years.

Plant Energy Loss Rates

Some of the energy content from campus plants is lost through inherent inefficiencies in the energy conversion and distribution processes. We used a Chilled Water Loss Rate of 5% which is the default value from the Clean Air Cool Planet Calculator. Steam losses were calculated as summarized in the table to the right.

	Main Campus	Health Sciences Campus
Steam Loss Rate	16.1%	6.5%
Chilled Water Loss Rate	5.0%	5.0%

STEAM DISTRIBUTION HEAT LOSS ANALYSIS

EAST CAROLINA UNIVERSITY - MAIN CAMPUS

	PIPE SIZE (IN)	PIPE LENGTH (FT)	HEAT LOSS PER FOOT (BTU/HR*FT)	HEAT LOSS (10^3 BTU/HR)	TOTAL ANNUAL HEAT LOSS (10^3 BTU/YR)	HEAT LOSS PERCENTAGE (%)	ANNUAL COST ($/YR)
TUNNEL - STEAM	16	250	210	53	460,535	0.2%	$ 5,757
	12	242	174	42	369,892	0.1%	$ 4,624
	10	1,890	152	288	2,521,256	1.0%	$ 31,516
	8	1,417	128	182	1,594,931	0.6%	$ 19,937
	6	483	106	51	447,661	0.2%	$ 5,596
	5	81	94	8	66,399	0.0%	$ 830
	4	320	81	26	227,475	0.1%	$ 2,843
	2	1,165	68	80	697,818	0.3%	$ 8,723
	1.5	200	60	12	104,974	0.0%	$ 1,312
	SUBTOTAL	6,048	---	741	6,490,941	2.5%	$ 81,137
TUNNEL - CONDENSATE	6	2,540	45	115	1,010,270	0.4%	$ 12,628
	4	703	34	24	209,463	0.1%	$ 2,618
	3	242	29	7	60,497	0.0%	$ 756
	2.5	81	25	2	17,774	0.0%	$ 222
	2	3,766	22	84	732,477	0.3%	$ 9,156
	1.5	378	19	7	64,341	0.0%	$ 804
	SUBTOTAL	7,710	---	239	2,094,822	0.8%	$ 26,185
DIRECT BURIED - STEAM	16	370	110	41	355,342	0.1%	$ 4,442
	12	7,672	94	719	6,296,238	2.4%	$ 78,703
	8	4,270	73	311	2,723,594	1.1%	$ 34,045
	6	1,907	62	119	1,040,264	0.4%	$ 13,003
	5	3,202	56	181	1,584,448	0.6%	$ 19,806
	4	3,534	51	178	1,563,555	0.6%	$ 19,544
	3	835	47	40	346,202	0.1%	$ 4,328
	SUBTOTAL	21,790	---	1,588	13,909,643	5.4%	$ 173,871
DIRECT BURIED - CONDENSATE	6	7,805	28	221	1,938,898	0.8%	$ 24,236
	4	4,928	23	112	985,008	0.4%	$ 12,313
	3	1,347	20	27	235,259	0.1%	$ 2,941
	2.5	1,083	18	20	172,082	0.1%	$ 2,151
	2	5,734	17	95	835,531	0.3%	$ 10,444
	1.5	305	15	5	40,418	0.0%	$ 505
	1	23	13	0	2,641	0.0%	$ 33
	SUBTOTAL	21,225	---	481	4,209,836	1.6%	$ 52,623
STEAM TRAPS	132 TRAPS	---	---	1,693	14,831,586	5.8%	$ 185,395
	SUBTOTAL	---	---	1,693	14,831,586	5.8%	$ 185,395
TOTAL		27,838	---	4,742	41,536,829	16.1%	$ 519,210

<u>NOTES:</u>

1. BASED ON 8,760 HEATING HOURS IN A YEAR.
2. BASED ON AN ANNUAL AVERAGE STEAM USE OF 292 MMLBS/YR.
3. BASED ON STEAM GENERATION COST OF $11 PER KILO-LB OF STEAM.
4. BASED ON 15% OF TRAPS FAILED OPEN. TRAPS ASSUMED TO HAVE 1/8 IN ORIFICE.

The following charts explain how the steam distribution losses were calculated for each of the campuses. The cost information used is an average steam cost based on a variety of institutions surveyed, including ECU's North Carolina university system peers. The 8760 heating hours used is the total number of hours in a year, which assumes the steam lines are energized for the entire year.

TOTAL ENTHALPY IN STEAM	1,189 BTU/LB
AVAILABLE HEATING ENTHALPY OF STEAM	880 BTU/LB
COST	$11 PER K-LB
STEAM WASTED PER MONTH PER TRAP	52,500 LB/MO/TRAP
% TRAPS FAILED	15%

STEAM DISTRIBUTION HEAT LOSS ANALYSIS
EAST CAROLINA UNIVERSITY - HEALTH SCIENCE CAMPUS

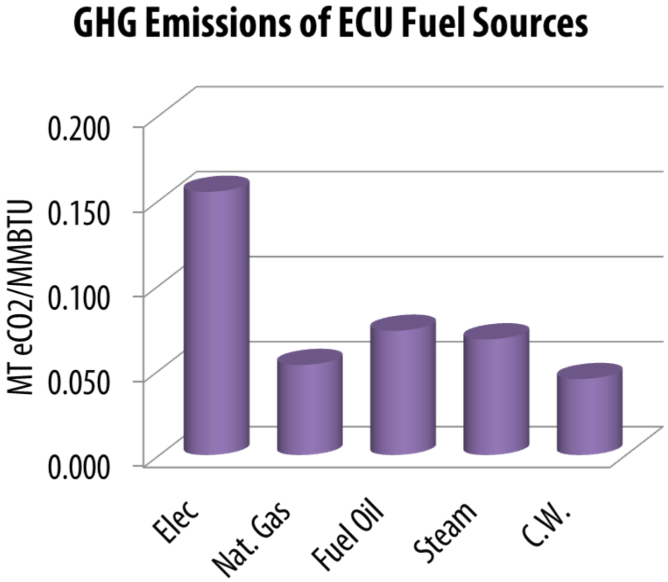
	PIPE SIZE (IN)	PIPE LENGTH (FT)	HEAT LOSS PER FOOT (BTU/HR*FT)	HEAT LOSS (10^3 BTU/HR)	TOTAL ANNUAL HEAT LOSS (10^3 BTU/YR)	HEAT LOSS PERCENTAGE (%)	ANNUAL COST ($/YR)
TUNNEL - STEAM	14	850	188	160	1,402,004	1.7%	$ 17,525
	SUBTOTAL	850	---	160	1,402,004	1.7%	$ 17,525
TUNNEL - CONDENSATE	8	850	56	48	416,651	0.5%	$ 5,208
	SUBTOTAL	850	---	48	416,651	0.5%	$ 5,208
DIRECT BURIED - STEAM	8	850	73	62	542,167	0.7%	$ 6,777
	6	1,468	62	91	800,790	1.0%	$ 10,010
	4	543	51	27	240,241	0.3%	$ 3,003
	SUBTOTAL	2,318	---	153	1,342,958	1.6%	$ 16,787
DIRECT BURIED - CONDENSATE	4	1,413	23	32	282,430	0.3%	$ 3,530
	3	905	20	18	158,062	0.2%	$ 1,976
	2	543	17	9	79,123	0.1%	$ 989
	SUBTOTAL	2,861	---	59	519,616	0.6%	$ 6,495
STEAM TRAPS	15 TRAPS	---	---	186	1,629,227	2.0%	$ 20,365
	SUBTOTAL	---	---	186	1,629,227	2.0%	$ 20,365
TOTAL		3,168	---	606	5,310,456	6.5%	$ 66,381

NOTES:

1. BASED ON 8,760 HEATING HOURS IN A YEAR.
2. BASED ON AN ANNUAL AVERAGE STEAM USE OF 92 MMLBS/YR.
3. BASED ON STEAM GENERATION COST OF $11 PER KILO-LB OF STEAM.
4. BASED ON 15% OF TRAPS FAILED OPEN. TRAPS ASSUMED TO HAVE 1/8 IN ORIFICE.

Estimating Greenhouse Gas Emissions

Knowing the fuel sources and distribution losses for the production of electricity, chilled water, and steam, it is possible to not only discuss the energy use of the campus, but also the GHG emissions associated with that energy use. Carbon dioxide is the largest greenhouse gas resulting from burning fossil fuels, but other greenhouse gases like methane and nitrogen dioxide are produced in lesser quantities. The measure of Carbon Dioxide Equivalent (eCO2) quantifies the emissions of carbon dioxide as well as the other greenhouse gases. eCO2 values were estimated using the Clean Air – Cool Planet Campus Carbon Calculator, (CACP CCC) customized to reflect the actual fuel sources for the Source 1 and 2 emission found at ECU. The chart below illustrates the relative GHG emissions associated with the various energy inputs found at ECU. Note that the emissions from a BTU of electricity is 2-3 times greater than from an equivalent amount of fuel oil and gas. The higher emissions associated with electricity is the result of two factors. First, coal, which has a higher emissions potential than natural gas or fuel oil, comprises 51% of the electricity fuel mix. Second, the higher emissions are a product of the inefficiencies of electricity generation and distribution For every 1 BTU of energy that arrives at a site, roughly 3 BTU's of energy are consumed at the source to overcome the extensive waste heat and transmission losses associated with the generation and transmission of electricity.



3. EXISTING CAMPUS ENERGY USE

Current Annual Energy Use and GHG Emissions

The annual energy use and GHG emissions for the 2011 calendar year (summarized below) were determined based on records of purchased and on-site energy use on campus. Using the CACP CCC, the GHG emissions that result from the operation of campus buildings were estimated to be 90,599 metric tons of carbon dioxide equivalent (MT eCO2). This translates to roughly 14.4 kg eCO2 per square foot of building.

MAIN CAMPUS

Building (Non-plant) Energy Use				
• Purchased Electricity	67,540,321	kWh	35,671	MT eCO_2
• Purchased Natural Gas	31,526,100	CF	1,718	MT eCO_2
• Purchased Fuel Oil	11,771	Gal	119	MT eCO_2
Chilled Water Plant	12,196,237	T-Hours		
• Purchased Electricity	11,785,439	kWh	6,224	MT eCO_2
Steam Plant	295,008	k-lbs		
• Purchased Natural Gas	367,685,700	CF	20,036	MT eCO_2
• Purchased Fuel Oil	8,500	Gal	86	MT eCO_2

HEALTH SCIENCE CAMPUS

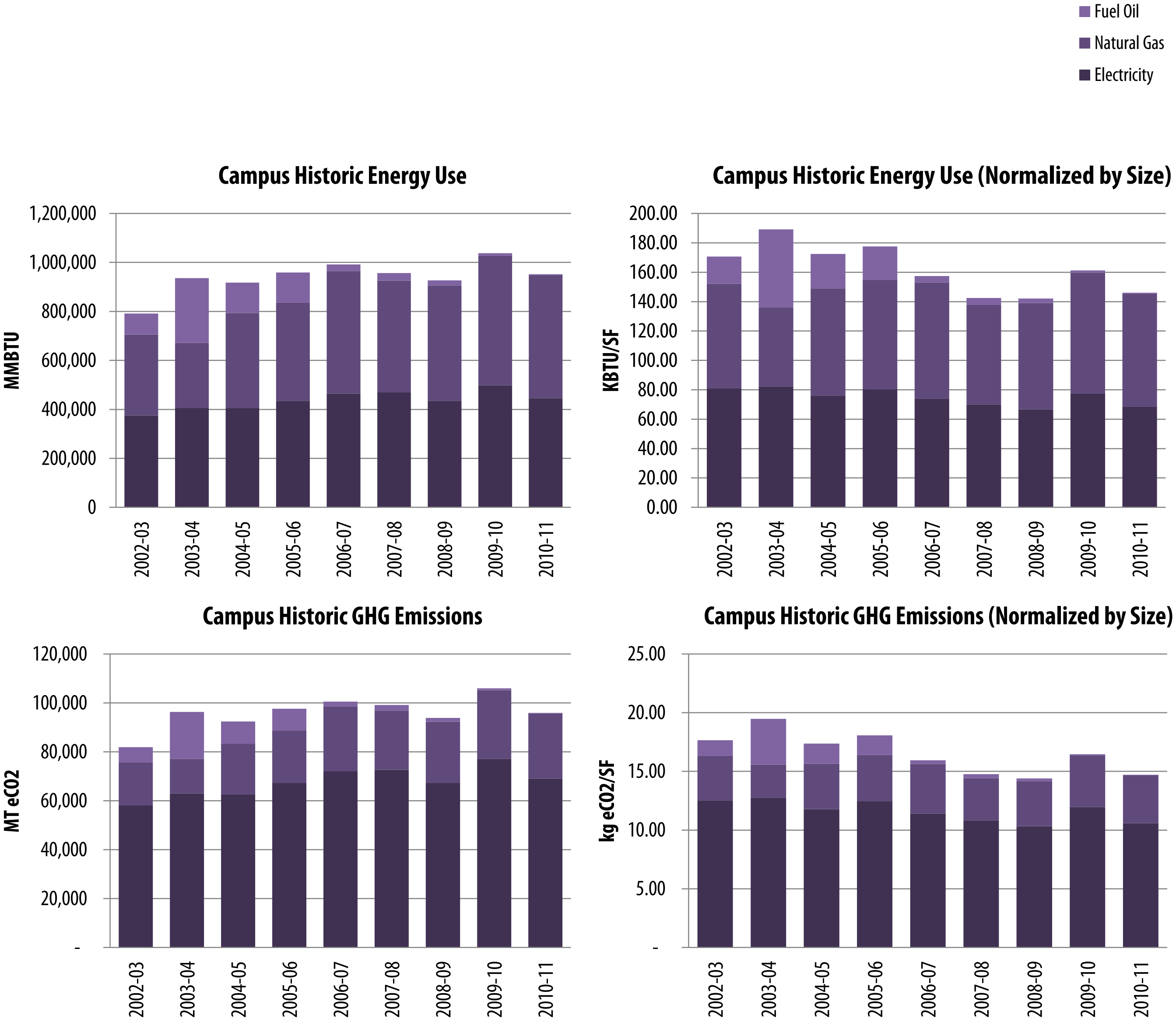
Building (Non-plant) Energy Use				
• Purchased Electricity	28,466,926	kWh	15,035	MT eCO_2
• Purchased Natural Gas	3,796,700	CF	207	MT eCO_2
• Purchased Fuel Oil	6,974	Gal	71	MT eCO_2
Chilled Water Plant	11,393,736	T-Hours		
• Purchased Electricity	8,723,474	kWh	4,607	MT eCO_2
Steam Plant	89,210	k-lbs		
• Purchased Natural Gas	124,715,600	CF	6,796	MT eCO_2
• Purchased Fuel Oil	2,698	Gal	27	MT eCO_2

Total GHG Emissions, 2011: 90,599 MT eCO_2

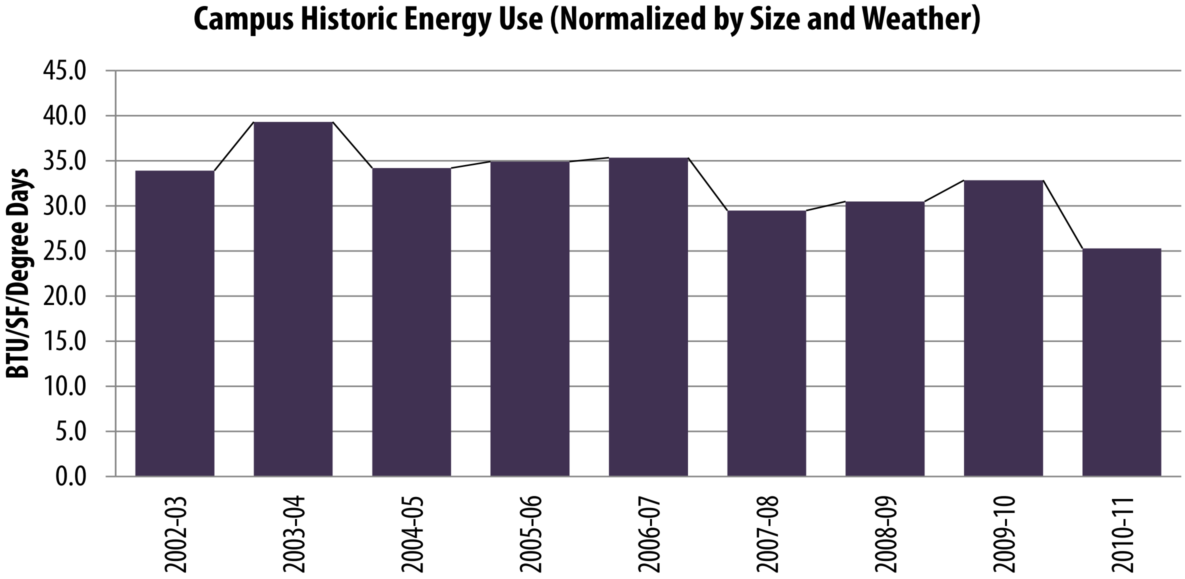
Historic Annual Energy Use

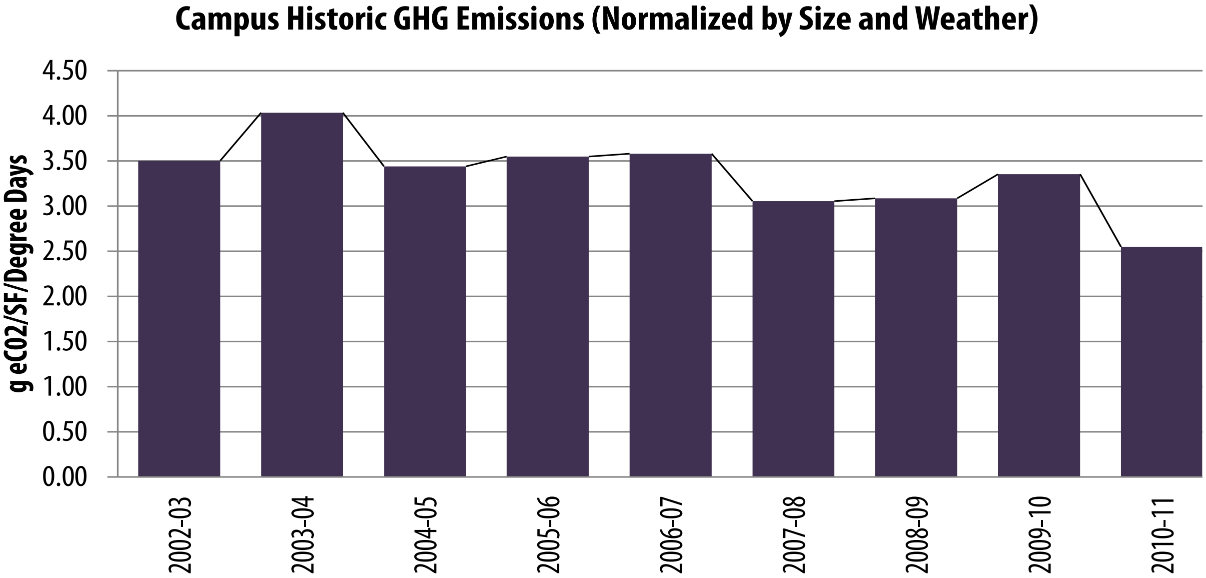
Historic energy consumption records were also analyzed to understand trends in campus energy use. In Fiscal Year (FY) 2002, the campus emissions are estimated to have been 81,191 MT eCO_2. Energy use over the past decade has slowly crept upward, as the campus grows and more energy-intensive activities occur within the built environment. Normalizing energy use and GHG emissions data by the size of the campus shows the campus energy intensity has trended downward over the past decade. These data show the impacts of ECU's conservation efforts over the past decade.

Fluctuations from year to year energy use can often be attributed to variations in seasonal temperatures. Using historic climate data, the Heating Degree Days and Cooling Degree Days for the past decade were also collected and used to normalize the energy use intensity data described above. The resulting analysis (shown on the next page) is the best indication of trends in energy conservation.



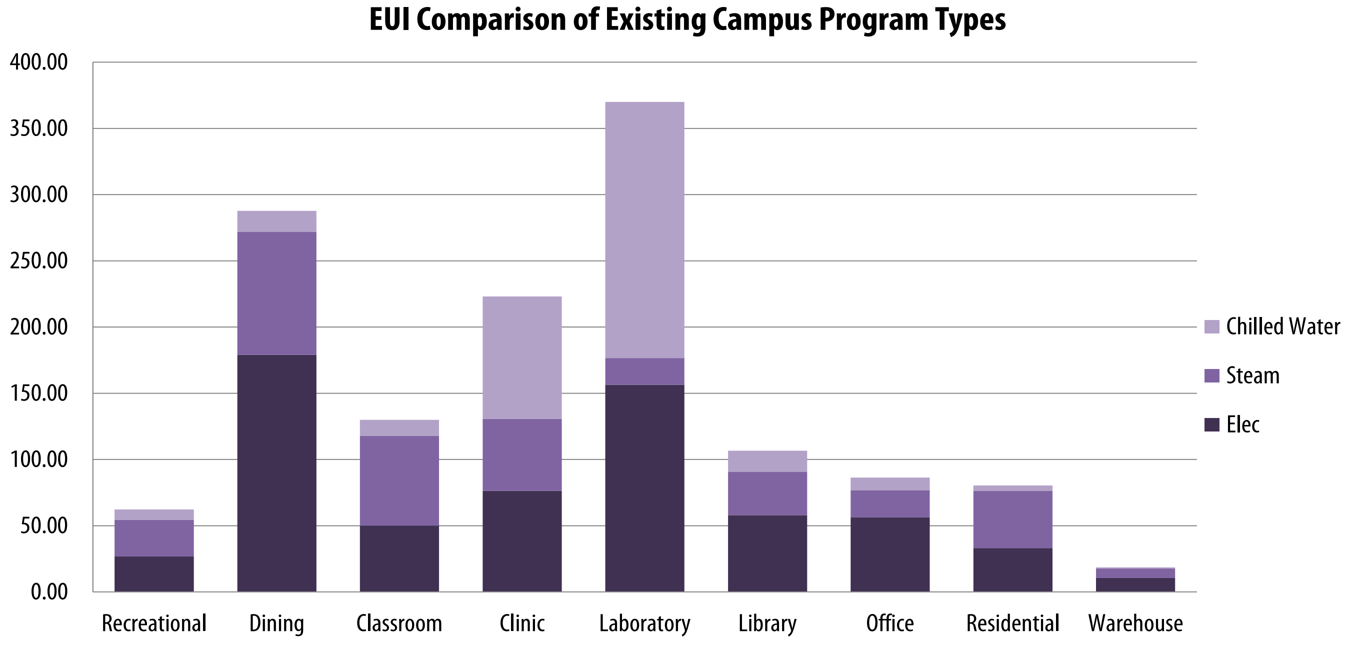
Energy use data normalized by both campus size and weather conditions show a more steady decrease in campus energy intensity / GHG emissions intensity, with the exception of a unusual, minor spike in energy use that occured during FY 2009. The campus has made aggressive strides in upgrading campus lighting through a relamping program as well as by upgrading lighting controls. Envelope upgrade projects and window replacements have improved the performance of older campus buildings. Upgrades to building HVAC system, including a VFD replacement effort, added economizer cycles, and retrofit commissioning have begun to improve building performance. Blow down heat recovery and chiller upgrades are underway and will improve the performance of campus central plants. Each of these measures have or will contribute to the reduction in the campus' energy impacts, made evident in the charts below. This reduction also demonstrates that the cumulative impact of smaller energy conservation measures can add up and yield a noticeable savings. This reality is the central idea of this report.





Predicting Energy Use of Existing Buildings, by Type

The energy intensity of buildings varies by program type. For example, a research building's energy use can be twice that of a general classroom building. Few buildings at ECU are metered individually, so to understand typical energy use by building type, the Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS) was used to establish typical energy intensities for the campus' program types. CBECS is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures.



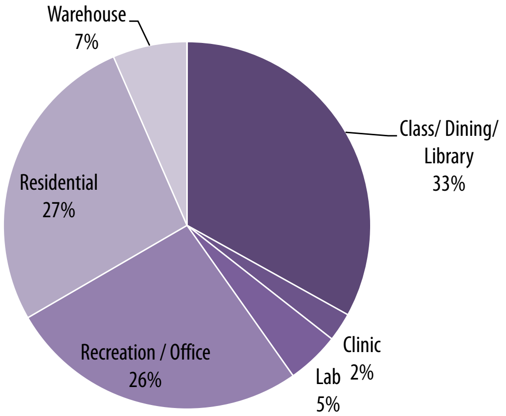
Correcting Energy Use Predictions to Account for Building Age

The energy data in CBECS include a range of buildings - some very new that were required to meet State of Federal energy codes, while others are 50-60 years old, constructed before energy codes began to be adopted. The chart below summarizes the history of energy code adoption in North Carolina. Starting in the mid-1990's, the State adopted increasingly stringent energy codes, which would suggest that new campus buildings would have better energy performance than those built before 1996. To account for the adoption of energy codes, we adjusted the EUI of campus buildings based on the year they were constructed or substantially renovated.

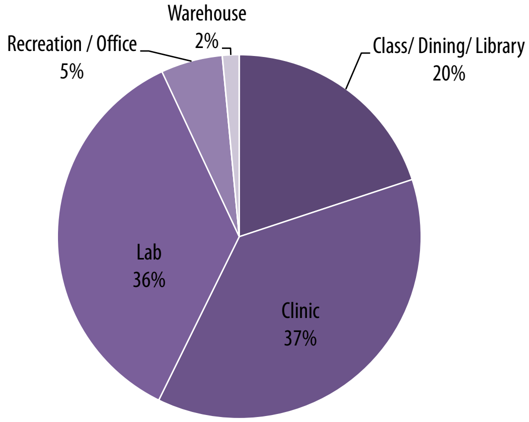
Time Frame	Energy Code Adopted	% Better than Average
0-1995	Nothing	0%
1996-2001	ASHRAE 90.1 v.1989	12%
2002-2006	2000 IECC	12%
2007-2008	2003 IECC	12%
2009-2011	2006 IECC	20%
2012-present	ASHRAE 90.1 v.2007	25%

By pro-rating the known, overall campus energy use by the distribution of building types by area, age, and the energy intensities of each building type, the overall energy use of each program type was projected. The charts on the next page illustrate the projected distribution of program types for each campus by size,energy, and emissions.

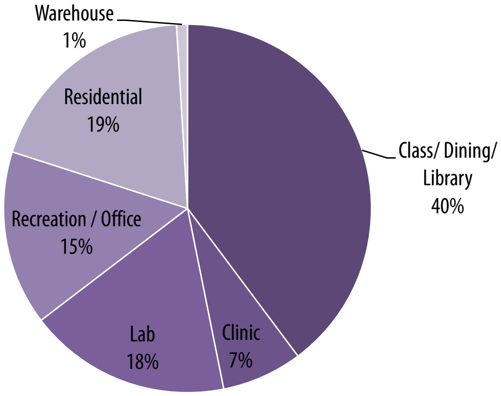
Existing Main Campus Make Up: Square Footage



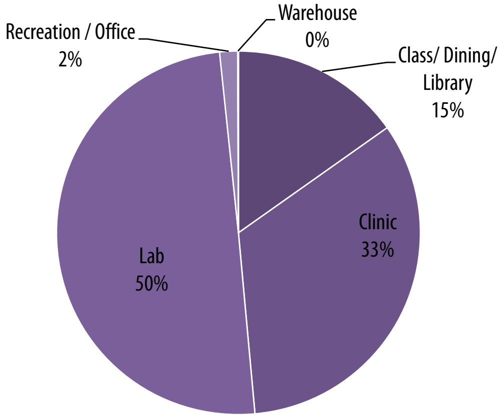
Existing HS Campus Make Up: Square Footage



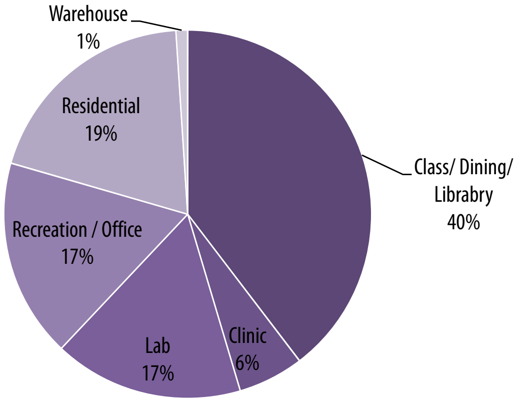
Existing Main Campus Make Up: Energy Use



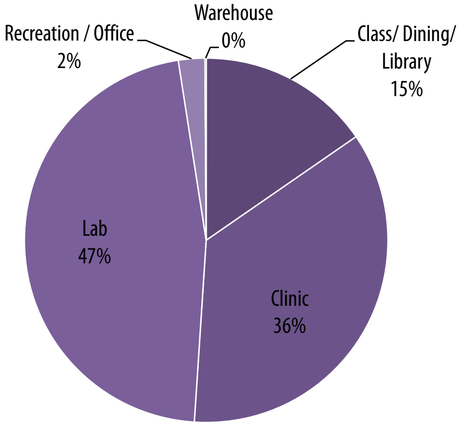
Existing HS Campus Make Up: Energy Use



Existing Main Campus Make Up: GHG Emissions



Existing HS Campus Make Up: GHG Emissions



4. PREDICTING FUTURE ENERGY USE

Modeling Planned Development

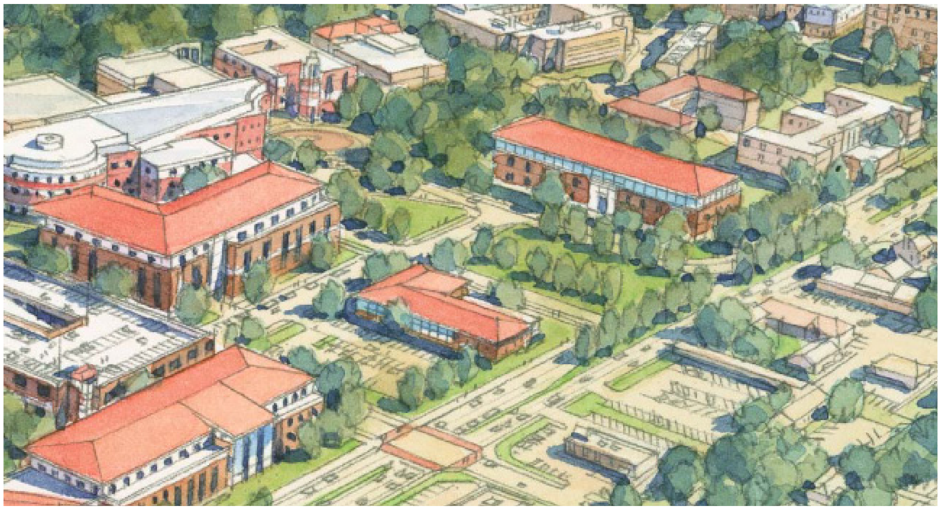
Over the next 18 years, the master plan provides for the addition of over 2.6 million square feet of new buildings. All new buildings and major renovations at ECU must meet or exceed the ASHRAE 90.1 – v. 2007 energy code. This minimum performance requirement is used to establish a baseline for future energy consumption. (Additionally, state-owned buildings must be designed, constructed, and certified to exceed the energy efficiency requirements of ASHRAE 90.1-2004 by 30% for new buildings, and 20% for major renovations.)

In order to understand how the planned growth of the campus would impact its energy use and GHG emissions as the Master Plan is implemented, energy modeling was used to predict the energy consumption of planned buildings. The following proposed program types were modeled, each conceptually described from within the master plan:

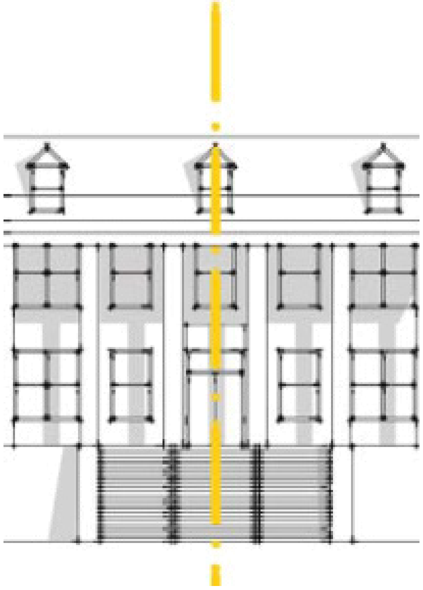
1. Administrative (Office) Buildings - based on the *Clinical Faculty Office Building* planned for the Health Sciences Campus;
2. Instructional (Classroom) Buildings - based on the *Academic A Building* planned for the Main Campus;
3. Laboratories - based on the *Life Sciences and Biotechnology Building* planned for the Main Campus;
4. Clincs - based on the *Ambulatory Clinics Building* planned for the Health Sciences Campus; and,
5. Dormitories - based on the *Belk Replacement (P1) Building* planned for the Main Campus.

The five buildings modeled (shown in red) are all new construction projects included within the Master Plan

Assumptions on the floor-to-floor height, fenestration patterns, and envelope materials were made using the typical campus architectural language and the minimum ASHRAE 90.1 requirements. The modeling results provide average energy intensities for buildings that comply with ASHRAE 90.1. Using these intensities, the energy use of future buildings was modeled. The results are specific to ECU. The climate was based on ECU's climate. The orientation, massing, and fenestration were derived from the Master Plan. The occupancy schedules were based on the campus' occupancy, and the temperature set points were based on the campus standards.



Images from the Master Plan were used to establish parameters for future buildings



Excerpt from the Architectural Design Guidelines show typical Windor-to-Wall Ratios on campus

	ECU Master Plan				
	Classroom	Lab	Clinic	Office	Residential
GSF	275,000	270,000	100,000	50,000	120,000
# of Stories	4	6	5	4	8
% Fenestration	35	35	35	35	35
# of people	2,500	675	1,000	194	225
floor-to-floor height	16'	16'	16'	14'	12'
Floor Plate Depth	100'	100'	100'	60'	50'
Floor Plate Length	688'	450'	200'	208'	300'
Orientation	SSW (22.5)	WNW (112.5)	SW (45)	SW (45)	SW (45)

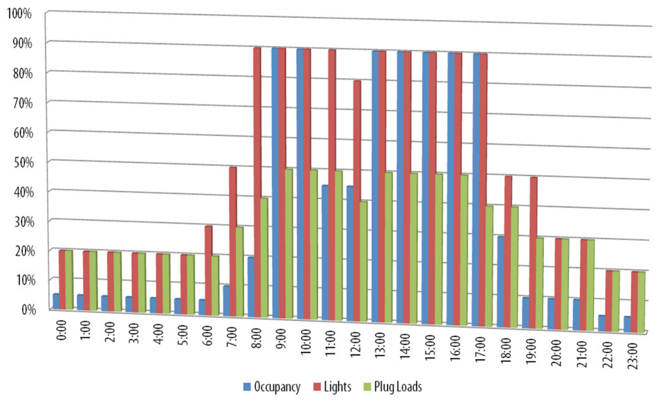
The table above summarizes the parameters used in the modeling of new buildings

The charts and tables below summarize the climate data, envelope thermal properties, baseline HVAC systems, temperature setpoints, internal loads, ventilation requirements, hot water demand, and building schedules used in the energy modeling. These values were either prescribed by ASHRAE 90.1 v.2007, by existing campus standards and policy, or by assumptions derived from the master plan.

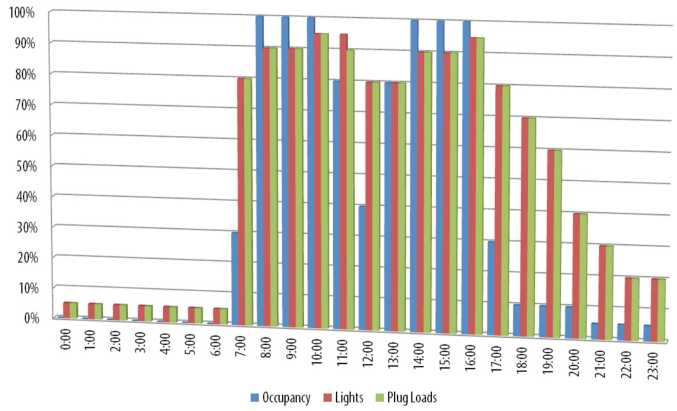
Common Energy Model ASHRAE 90.1 Baseline Parameters										
Weather				Envelope Thermal Properties				HVAC System		
Summer		Winter	Climate Zone	Wall U-Value	Roof U-Value	Glazing U-Value	Glazing SC	Type	Fan Control	Economizer
Dry Bulb (F)	Wet Bulb (F)	Dry Bulb (F)								
95.2	76.9	20.9	3A	0.084	0.048	0.65	0.25	VAV w/ Reheat	VFD	Fixed Dry Bulb

Energy Modeling Parameters Varying By Building Type															
Building Type	Thermostat Setpoints				Internal Loads			Airflow				HVAC System			Domestic Hot Water
	Cooling (F)	Heating (F)	Drift (F)	RH %	Occupants (SF/occ)	Misc Load (W/SF)	Lighting (W/SF)	Ventilation (cfm/occ)	Ventilation (cfm/SF)	Infiltration (ACH)	Minimum SA (ACH)	Exhaust / Hood	Total Exhaust	Recovery	Average Daily Gal/Person
Classroom	76	68	82/62	NA	110	1.5	1.2	7.5	0.06	0.3	NA	NA	NA	NA	2
Lab	76	68	82/62	50	400	8.0	1.2	100%	100%	0.3	6	900 CFM	100%	50% Eff	10
Clinic	76	68	82/62	50	100	2.0	1.0	5	0.25	0.3	6	NA	NA	NA	10
Office	76	68	82/62	NA	257	1.5	1.0	5	0.06	0.3	NA	NA	NA	NA	1
Residential	76	68	82/62	NA	533	1.0	1.0	5	0.06	0.3	NA	NA	NA	NA	13

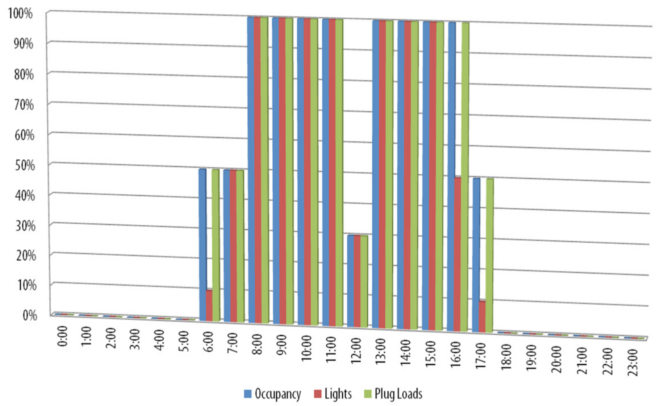
Lab / Clinic Schedules



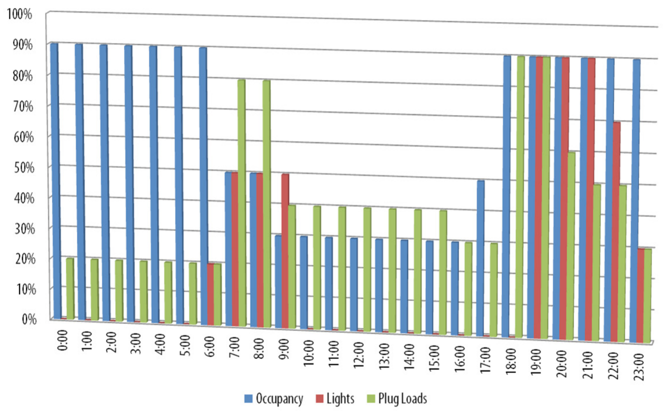
Office Schedules



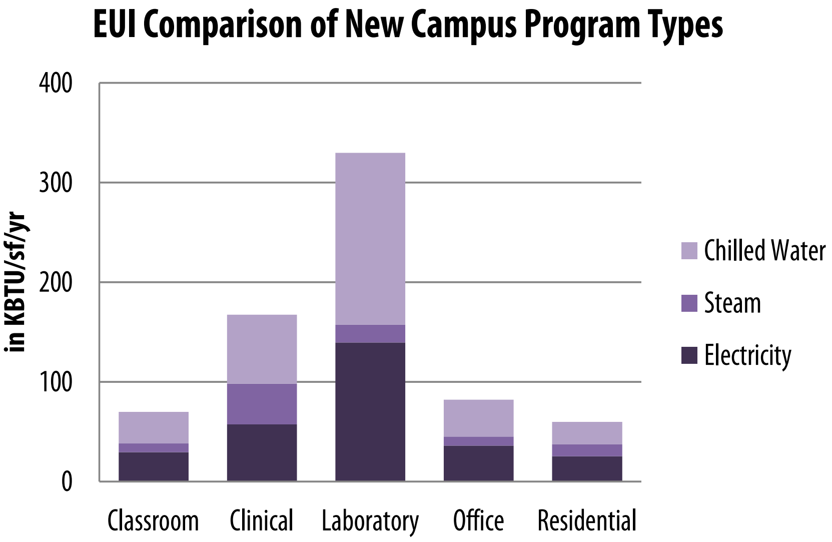
Classroom Schedules

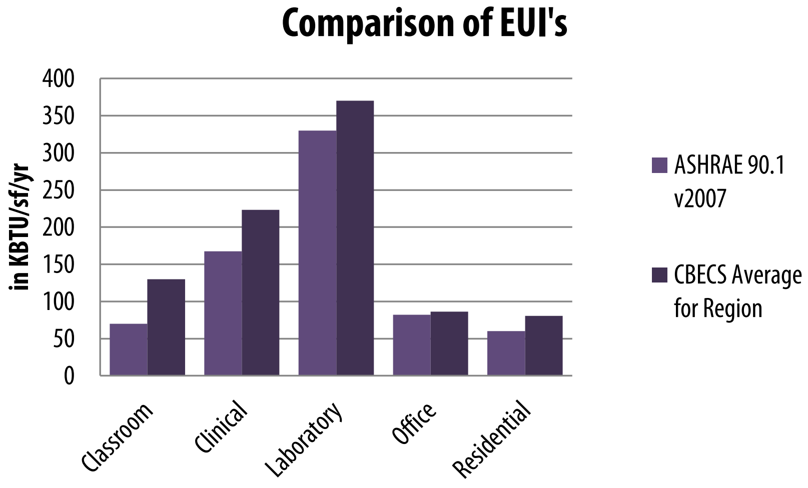


Residential Schedules



Based on the assumptions outlined on the previous pages, the predicted EUI (total, as well as the break-out by energy sources) was determined. These values are used as the basis for predicting the energy use of the campus as the Master Plan is implemented, and are summarized in the table below.





	Basis for 90.1 v.'07 compliant New Buildings			
	EUI	Elec EUI	Steam EUI	CW EUI
Classroom	69.86	29.57	8.73	31.56
Clinical	167.32	57.24	40.82	69.26
Laboratory	329.70	139.44	17.96	172.29
Office	82.18	36.06	9.18	36.95
Residential	59.97	25.43	11.72	22.82

It should be noted that modeling indicated that the new buildings planned for the campus will not be significantly more efficient than the average typical existing campus building. This is uncharacteristic, as typically ASHRAE 90.l v.2007 compliant buildings are 25% more efficient than an average building. The comparatively high energy use of the modeled buildings may be the result of conservative assumptions used in modeling new buildings as well as the difficulty in doing predictive energy modeling based on highly conceptual planning.

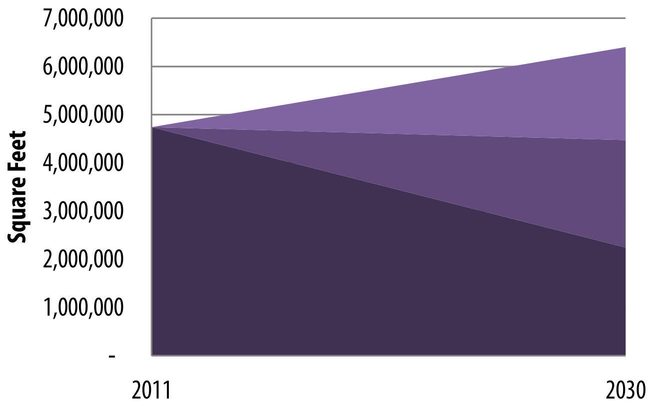
Using the predicted EUI values for new construction, along with the estimated EUI values for existing buildings, it is possible to depict how campus energy use would change over time as the ECU Master Plan is implemented. Since energy modeling not only predicted total EUI, but also the fuel source demand for the Master Plan program types (EUI chilled water, EUI steam, EUI electricity), it is possible to illustrate how the campus GHG emissions would evolve as the Master Plan is implemented.

The charts on the following pages depict the evolution in campus size, energy use, and GHG emissions, by campus. The Main Campus will grow by 35% but will reduce its energy use by 2.64%. This paradox can be explained by outdated buildings planned for demolition being replaced with more efficient, code-compliant buildings, and the planned renovations of the existing building stock, bringing them up to code. This growth, however, does lead to a nearly 5% increase in GHG emissions. There is not a linear relationship between Energy Use and GHG emissions. Newer buildings rely less on steam and more on electricity. This shift might be attributed to the inherently inefficient exterior envelope of older buildings, which places a greater demand on heating than in new buildings with exterior envelopes designed to meet stringent code requirements. Since the GHG emissions of 1 KBTU of steam are 44% of that of 1 KBTU of electricity, a shift from steam reliance to electricity reliance would cause GHG emissions to grow even while overall energy use diminishes. The Health Sciences Campus will grow by over 60% but will only increase its energy use by just over 25%, and increase is GHG emissions by just over one third.

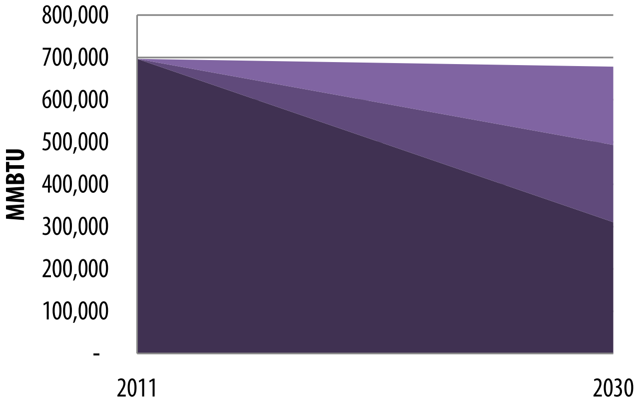
Impacts on Size, Energy, and Emissions from Implementing the Master Plan

Main Campus

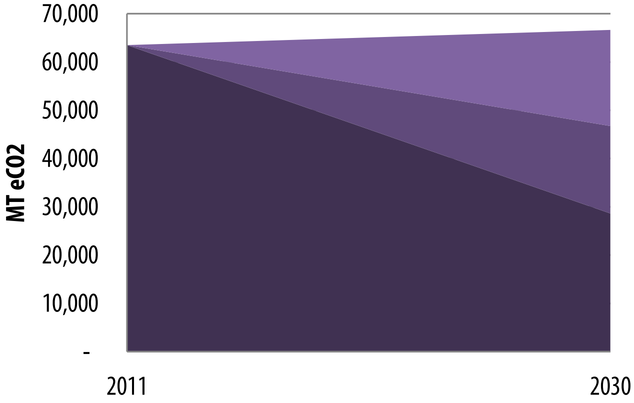
Change in Campus Make Up: Square Footage



Change in Campus Make Up: Energy Use

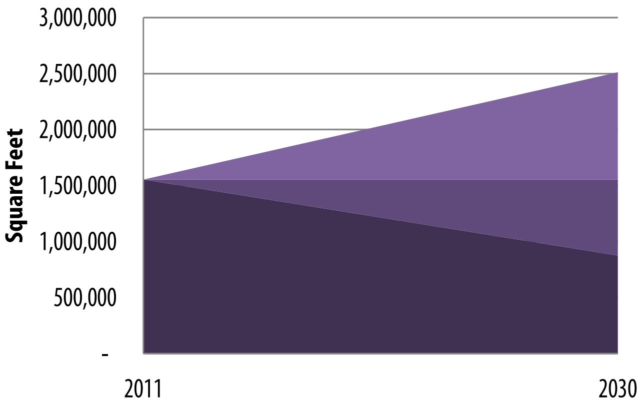


Change in Campus Make Up: GHG Emissions

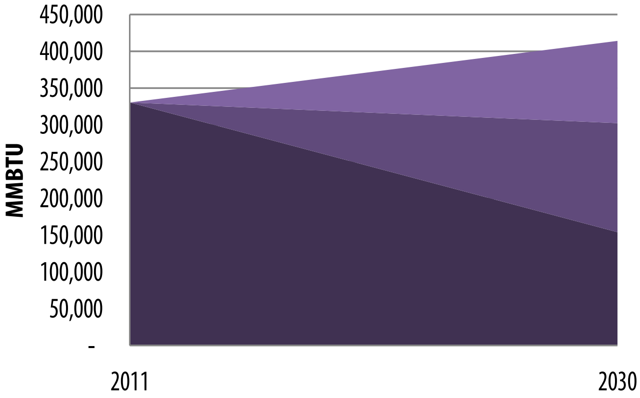


Health Science Campus

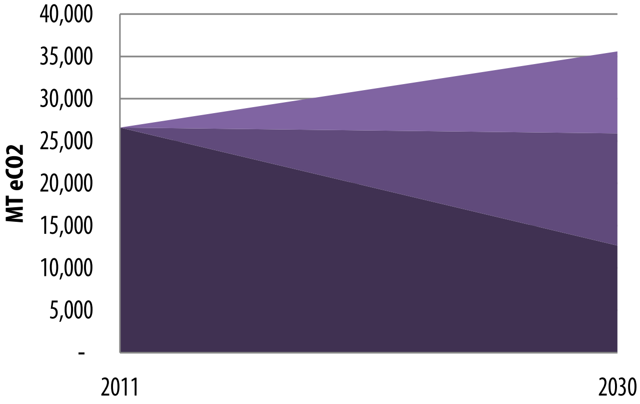
Change in Campus Make Up: Square Footage



Change in Campus Make Up: Energy Use



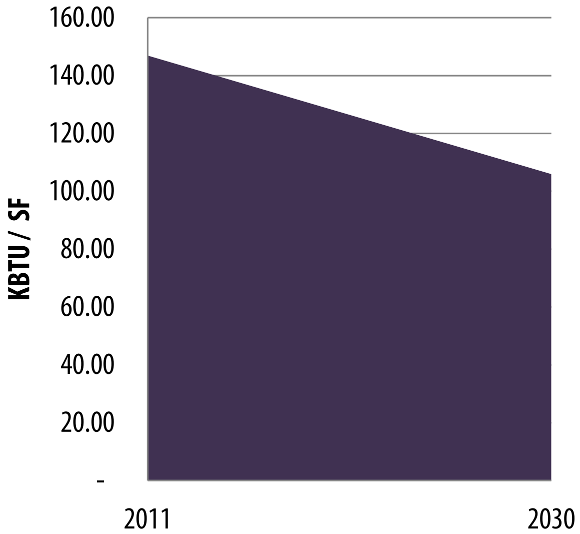
Change in Campus Make Up: GHG Emissions

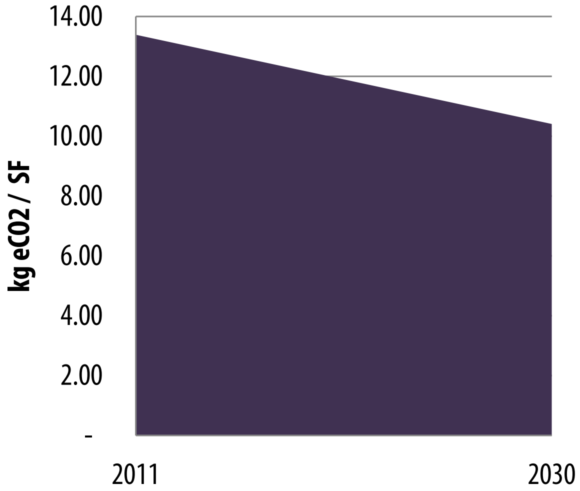


■ New Construction ■ Renovation ■ Existing Stock

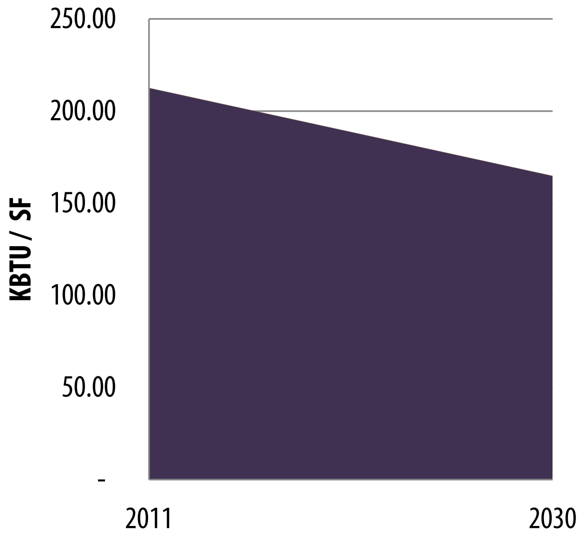
In order to better understand the energy and GHG emissions trends that result from the implementation of the master plan, the charts below show the change in Energy and GHG Emissions Intensity, which normalize consumption data by the changing size of the campus. The implementation of the master plan will result in the Main Campus' energy use intensity dropping by 27.9% and its GHG emissions intensity dropping by 22.3%. The implementation of the master plan will result in the Health Sciences Campus' energy use intensity dropping by 22.5% and its GHG emissions intensity dropping by 17.2%.

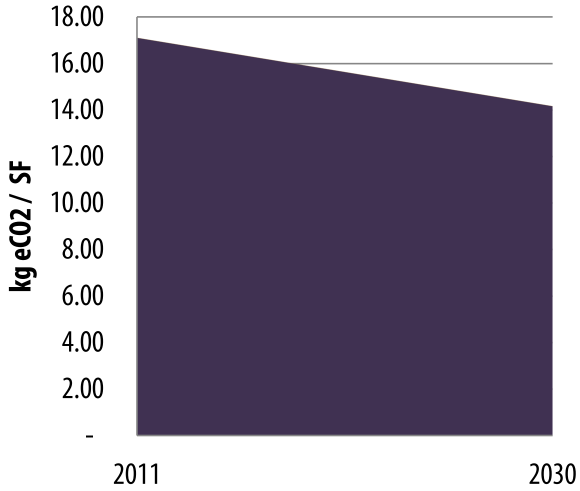
Main Campus


Change in Campus Make Up: EUI

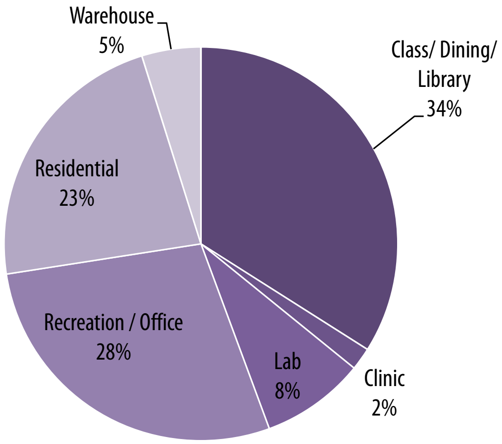

Change in Campus Make Up: Emissions Intensity

Health Science Campus

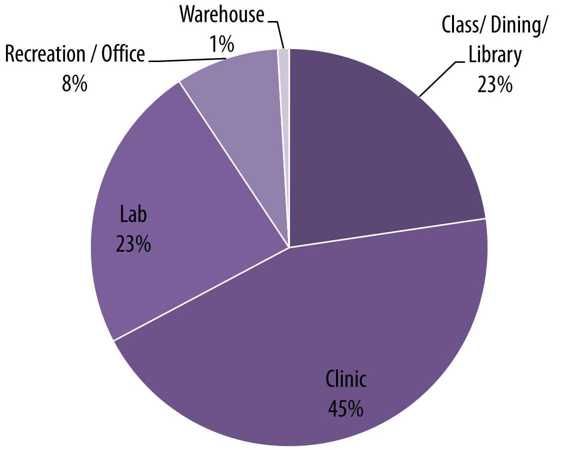

Change in Campus Make Up: EUI


Change in Campus Make Up: Emissions Intensity

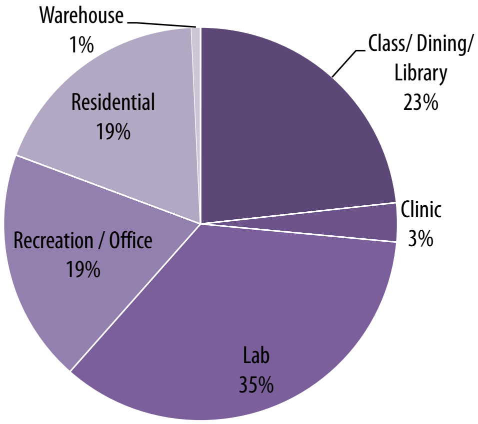
2030 Main Campus Make Up: Square Footage



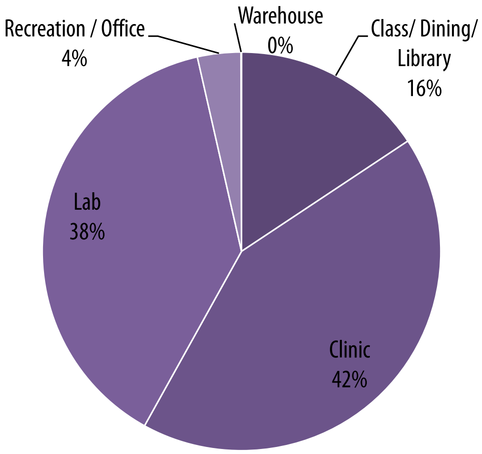
2030 HS Campus Make Up: Square Footage



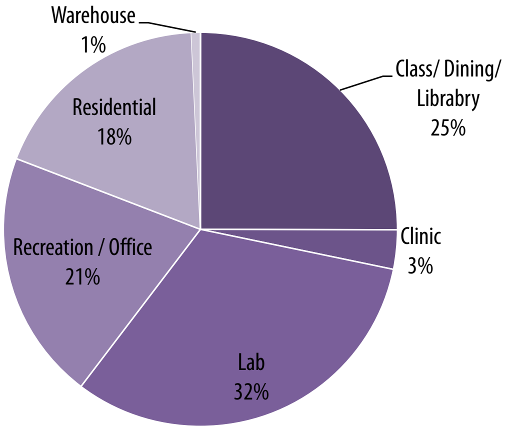
2030 Main Campus Make Up: Energy Use



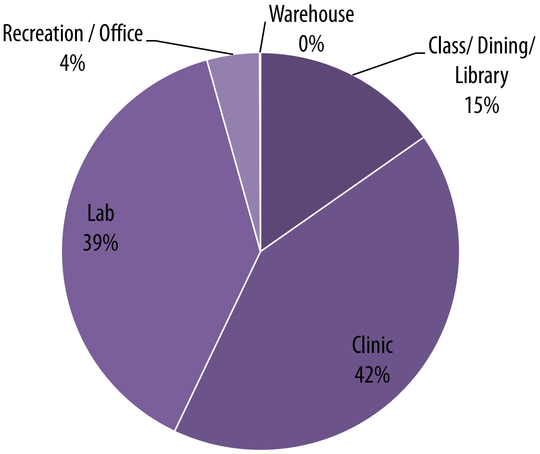
2030 HS Campus Make Up: Energy Use



2030 Main Campus Make Up: GHG Emissions



2030 HS Campus Make Up: GHG Emissions



5. THE AMERICAN COLLEGE & UNIVERSITY PRESIDENTS CLIMATE COMMITMENT

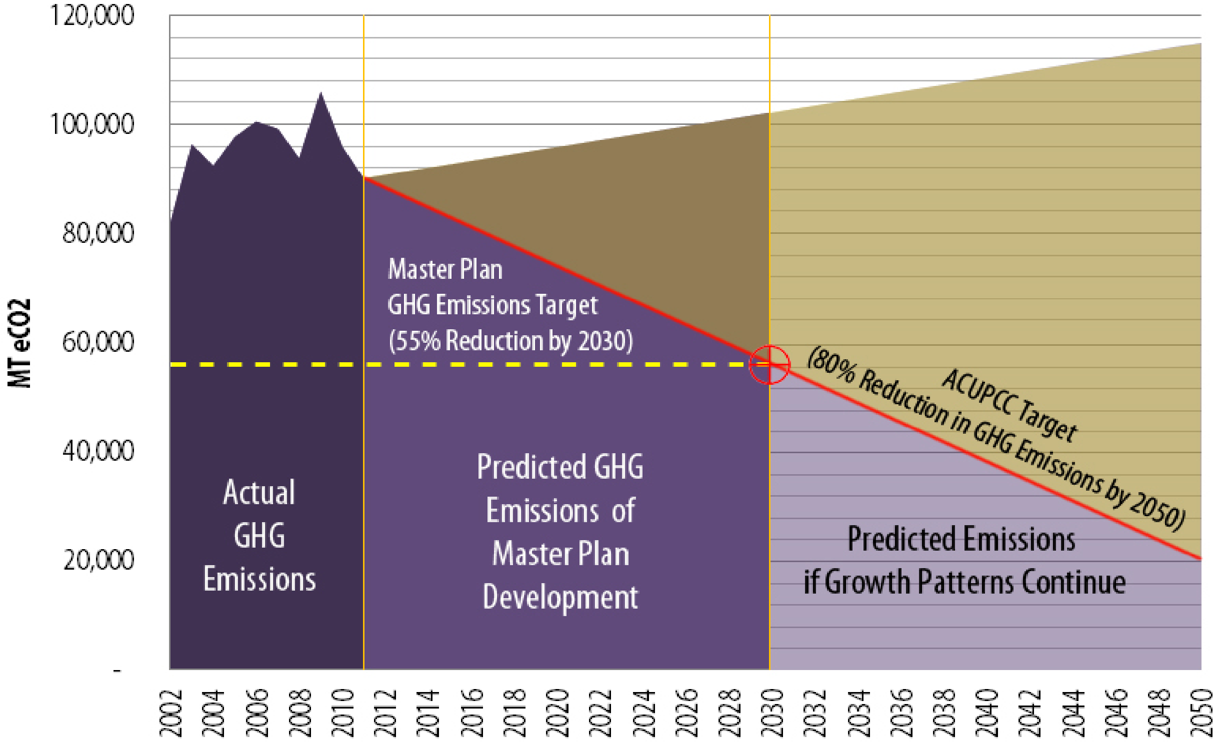
The American College & University Presidents Climate Commitment (ACUPCC) is a pledge signed by college and university presidents to implement comprehensive plans to achieve climate neutrality as soon as possible. The pledge includes the following:

> *"We further recognize the need to reduce the global emission of greenhouse gases by 80% by mid-century at the latest, in order to avert the worst impacts of global warming and to reestablish the more stable climatic conditions that have made human progress over the last 10,000 years possible."*

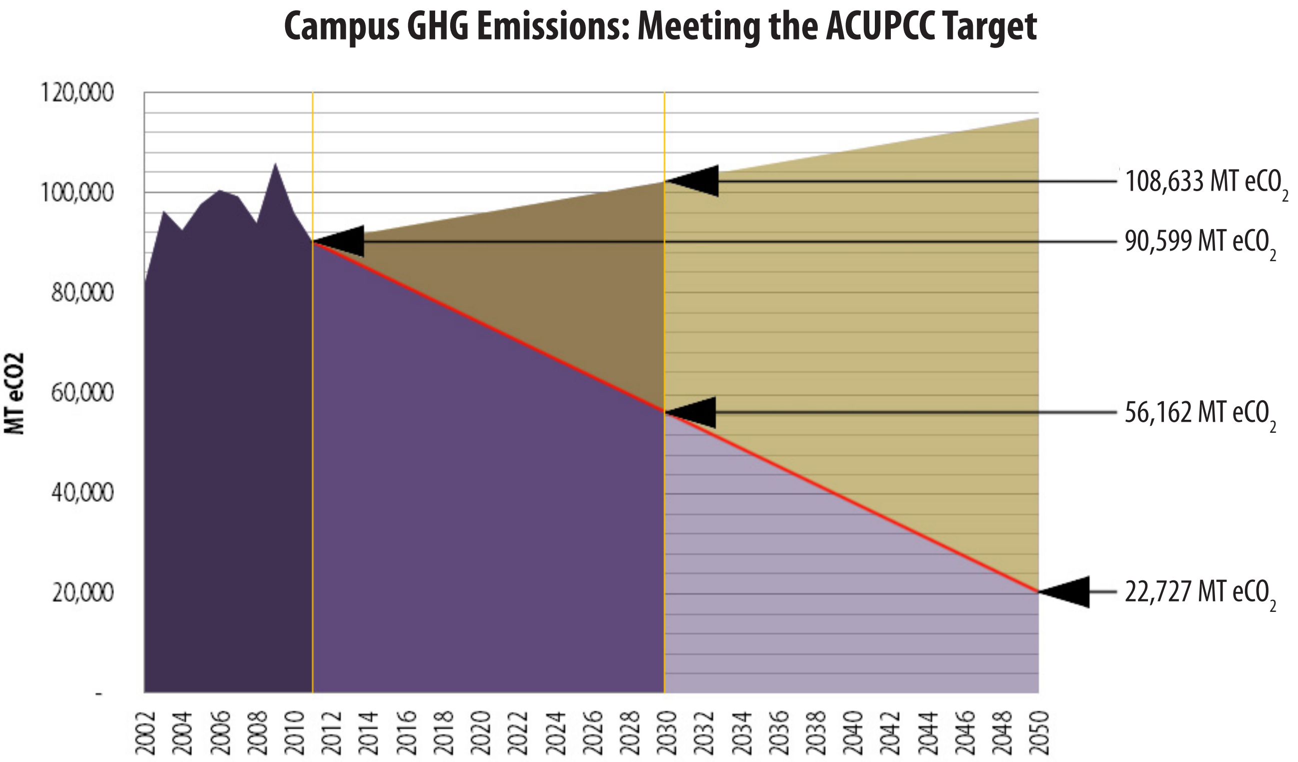
At the time of this report, over 660 institutions of higher learning around the country have signed ACUPCC, and the pledge is gaining momentum amongst colleges and universities as a new standard for a greenhouse gas emissions reduction target.

The chart below illustrates the historic GHG emissions determined from campus purchased energy records, the predicted emissions for the master planned campus implemented between now and year 2030 (using the campus energy use model discussed in the last section), and a prediction of the campus GHG emissions up to year 2050 (the ACUPCC deadline for reducing GHG emissions by 80%) based on a continuation of the pattern of emissions predicted over the next 18 years. The top line represents the predicted emissions if no improvements are made. The ACUPCC target is overlayed on this chart to illustrate how the ACUPCC emissions reduction target compares to the predicted emissions. To get on track towards the ACUPCC required 80% reduction in GHG emissions by 2050, a 55% reduction in GHG emissions should be targetted for year 2030, when the master plan is envisioned to be implemented. If GHG emssions reductions keep to this pace, the ACUPCC goal can be reached.

Campus GHG Emissions: Meeting the ACUPCC Target



The chart below identifies specific GHG emissions targets for each of these milestones. As discussed earlier, the Year 2011 emissions were measured at 90,599 MT eCO_2. The GHG emissions of the campus in year 2030, upon implementation of the planned new projects, renovations, and demolitions envisioned in the master plan, were predicted to be 108,633 MT eCO_2, a 20.74% increase in GHG emissions. If that 20.74% rate of increased GHG emissions continues at the same pace until 2050, the campus GHG emissions would be 113,635 MT eCO_2. The ACUPCC target would be to reduce those emssions by 80%, or to have campus emissions in 2050 not exceed 22,727 MT eCO_2. To stay on path to meet that target, then by 2030 (when the master plan is implemented) the campus should target 56,162 MT eCO_2 or less as the total campus GHG emssions associated with the operation of campus buildings.



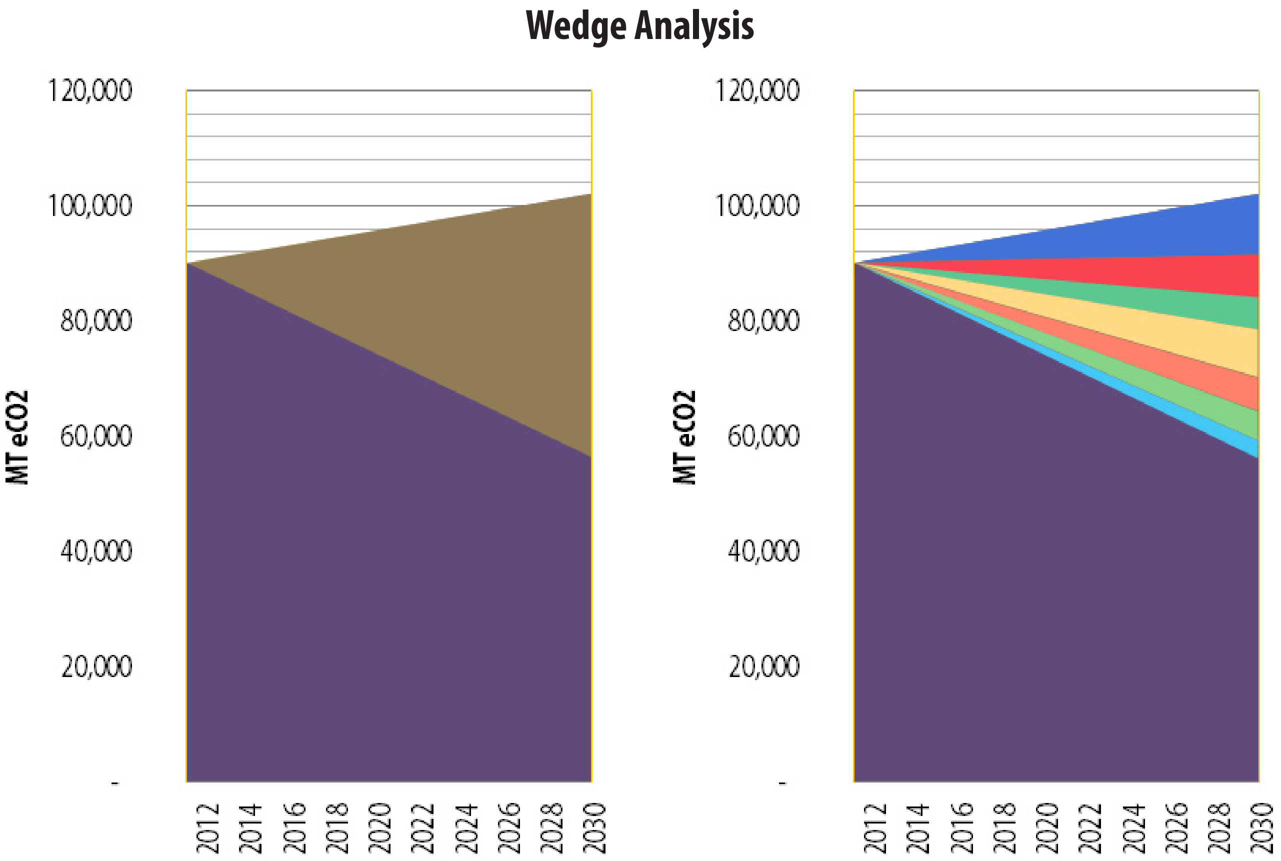
6. ESTABLISHING ENERGY CONSERVATION STRATEGIES

Wedge Analysis

The remainder of this report focuses on identifying measures that will allow the campus to grow by over 40% as envisioned in the master plan, while reducing the campus GHG emissions towards the target of 56,162 MT eCO_2 or less. This target can be achieved by implementing a number of sustainable design practices to both the planned and existing building stock. Each of these practices will reduce the overall campus emissions and each of the colored wedges in the chart below represents the emissions reduction potential associated with each approach. No one strategy, or "wedge" alone can reach the ACUPCC target, but rather the cumulative effect of combined strategies can reach and even exceed the target.

The selection of the wedges studied in this report used the following framework:

- understanding the building types prevalent at ECU and their energy use distribution, and
- understanding the climate at ECU in order to select approaches well suited to this climate region.



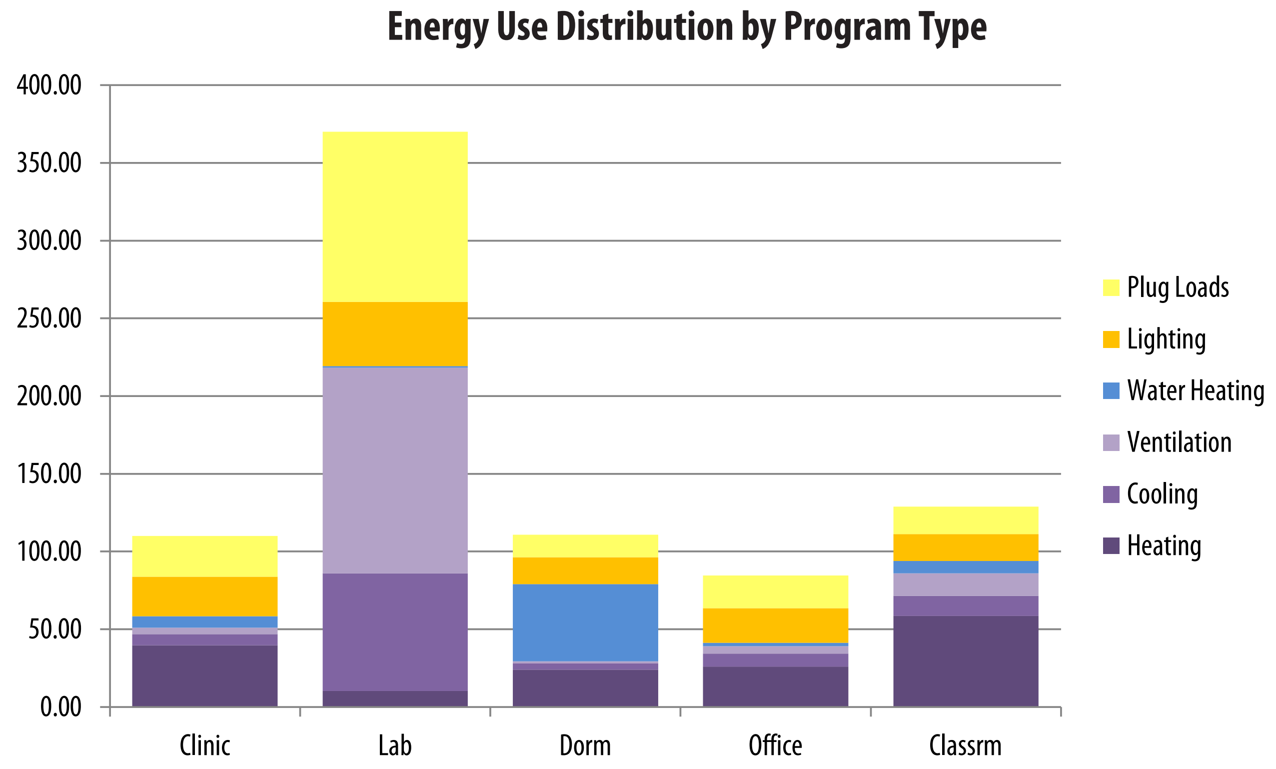
Understanding Energy Use

Identifying the most effective energy conservation strategies begins by understanding the energy use distribution within campus buildings. Not only is the CBECS database useful for illustrating the typical total energy use of US Buildings within a given region and program type, it also provides typical data for the energy use distribution within those buildings. The energy use distributions for the program types found at ECU are illustrated in the table below. These results are often intuitive; for example, it is not surprising that the energy use for water heating represents a greater portion of the overall energy use in a residential building than for an academic building.

One caveat with the CBECS data is that within a given region, there may be a shortfall of program types in the database. This shortfall can result in anomalies making it difficult to predict typical patterns. For example there is a shortfall of research buildings in the database. CBECS data was adjusted using actual data from similar project types in an effort to make reliable predictions for the energy use distribution of research buildings.

The CBECS data that is available suggests the following conclusions:

- Space heating in all program types except perhaps laboratories is a significant portion of the campus energy use, so basic envelope improvements can yield significant energy savings.
- For all program types, lighting represents a significant portion of the building's energy use. High-efficiency lighting strategies should be pursued.
- Water heating is a significant portion of residential buildings' energy use. Solar thermal strategies should be considered for future residential projects.
- The higher ventilation rates of research buildings increases space heating and cooling energy use, so energy recovery strategies can have significant benefits.

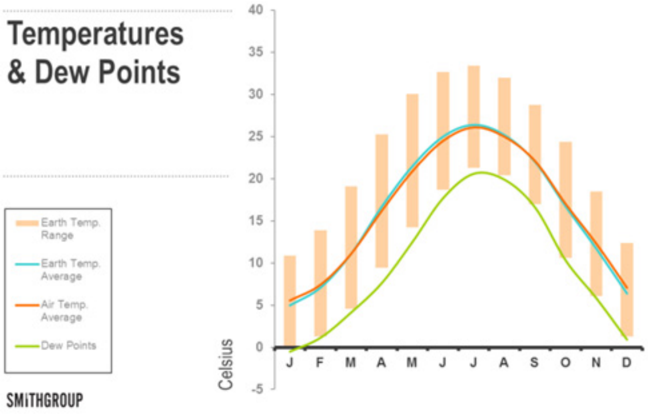


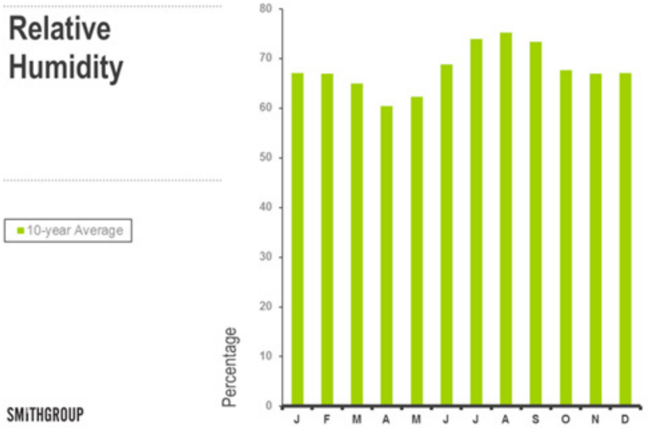
Understanding Climate

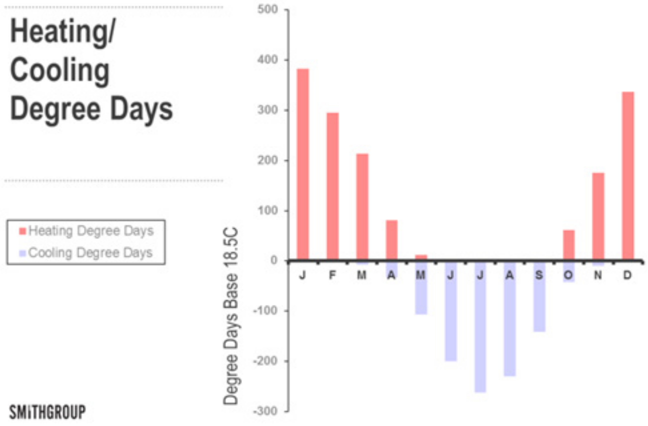
Energy conservation is most easily achieved when architectural design is rooted in an understanding of regional climate. Passive and active design approaches that work in harmony with a regional climate are often the most successful and cost effective design approaches. The annual average temperature for Greenville, NC is nearly 60°F and buildings in this climate are cooling-dominant, although, based on historic records of campus steam use, heating demand is not insignificant. Some program types on campus, like classrooms and office programs, are external-load driven meaning the performance of the exterior envelope plays a significant role in the energy consumption of the building. Other program types, like laboratories and clinics, tend to be more internal-load driven, with internal equipment or ventilation requirements playing the significant role in the building's energy use.

For external-load driven program types, passive solar strategies, such as south-facing glazing with exterior sun shades, can harness the sun's heat during winter months. The envelope's insulation values also become critical consideration. Improving R-values of glazing, wall, and roof assemblies can improve energy performance, and the initial investment will often quickly pay for itself over the life of the building.

While the summer months have high temperatures and humidity, Spring and Fall have favorable temperatures with lower humidity, enabling passive cooling approaches like natural ventilation or economizer cycles for some program spaces. A mixed-mode ventilation system with operable windows and building controls that shut down HVAC systems when windows are open can reduce space cooling and ventilation loads for a significant portion of the school year. For spaces with high mechanical ventilation rates, like laboratories or clinics, total energy recovery systems are well-suited for this hot, humid climate, recovering both the latent and sensible energy from exhaust air.

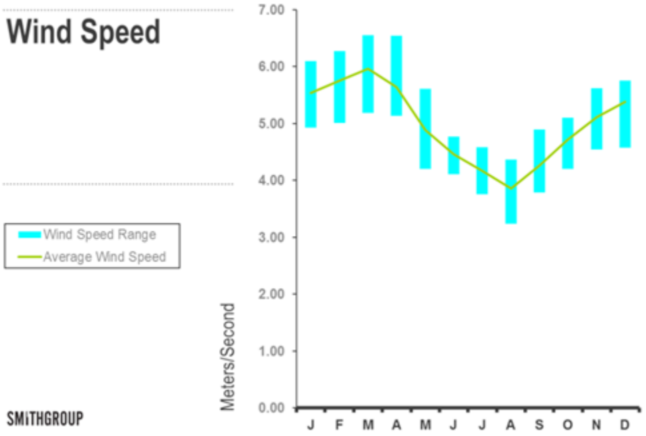


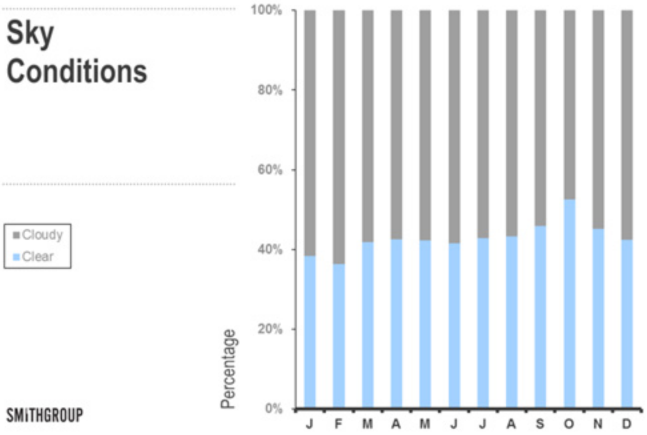


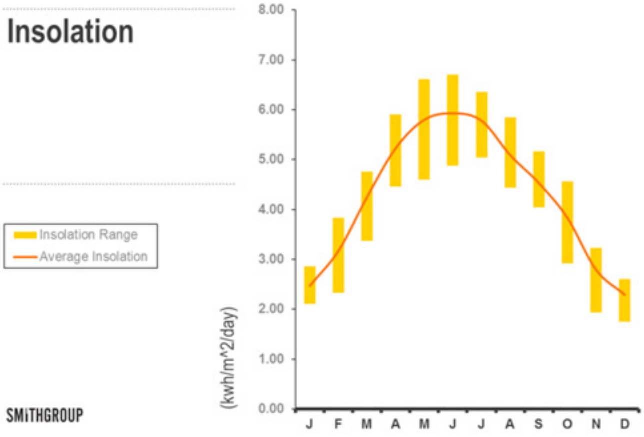


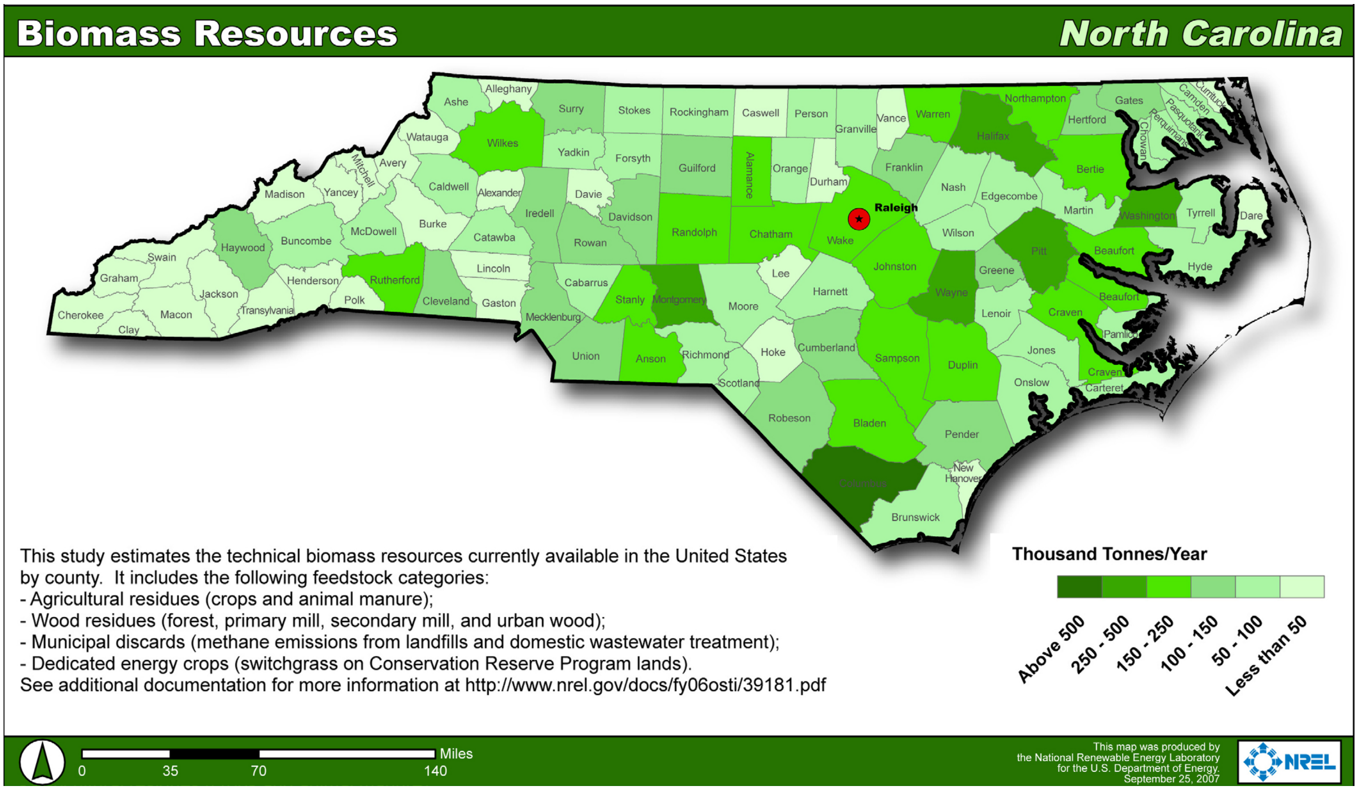
Solar insolation is quite high supporting active solar strategies like photovoltaics; however, regional sky conditions are predominantly cloudy which limit the effectiveness of photovoltaics. Cloudy skies are ideal for daylighting, allowing buildings to harness extensive natural light without significant glare or solar heat gain. When combined with daylight sensors and dimmable or stepped artificial lighting, daylighting can result in significant energy savings. While cloudy skies are not ideal for photovoltaics, solar thermal strategies would still be suitable given the regional insolation. Residential projects with large domestic hot water demands would be good candidates for solar thermal approaches.

Greenville does not have suitable wind speeds to support onsite wind turbines used to produce electricity from wind resources. Wind has a significantly higher potential 50 miles east of Greenville within the Pamlico Sound. A map of the availability for biomass resources within the State reveals that Pitt County has good potential for biomass. Biomass sources can be used to create biofuels to power campus steam production, and potentially to power turbines that produce electricity.









Biomass Resources North Carolina

This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:

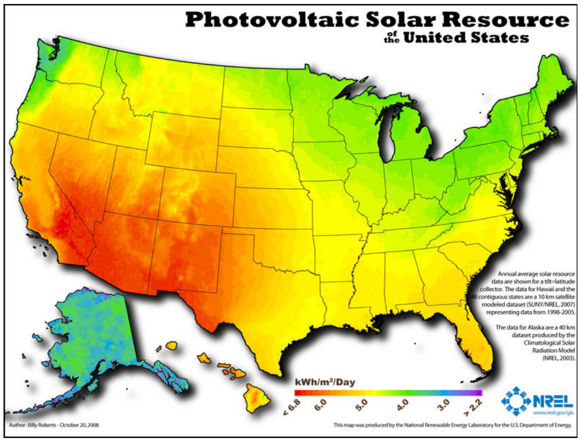
- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (switchgrass on Conservation Reserve Program lands).

See additional documentation for more information at http://www.nrel.gov/docs/fy06osti/39181.pdf

Thousand Tonnes/Year

🟩	🟩	🟩	🟩	🟩	🟩
Above 500	250 - 500	150 - 250	100 - 150	50 - 100	Less than 50

This map was produced by
the National Renewable Energy Laboratory
for the U.S. Department of Energy.
September 25, 2007



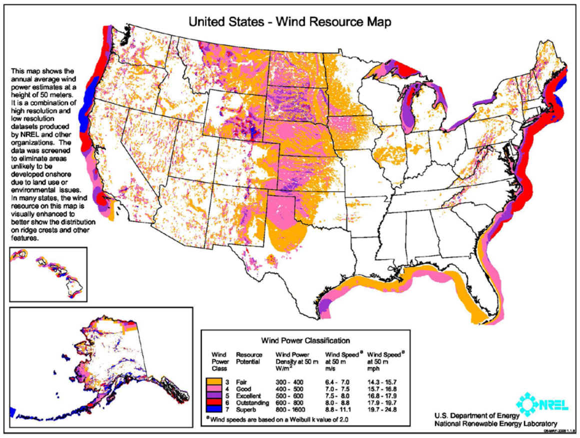
Photovoltaic Solar Resource of the United States

Annual average solar resource data are shown for a tilt=latitude collector. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

Author: Billy Roberts - October 20, 2008

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.



United States - Wind Resource Map

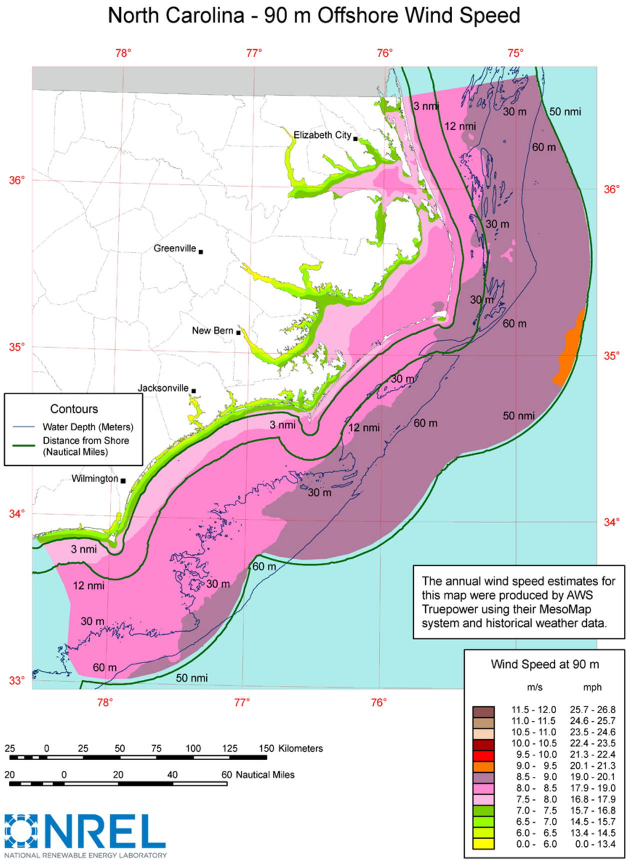
This map shows the annual average wind power estimates at a height of 50 meters. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

Wind Power Classification

	Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
🟧	3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
🟪	4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
🟪	5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
🟥	6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
🟦	7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory



North Carolina - 90 m Offshore Wind Speed

The annual wind speed estimates for this map were produced by AWS Truepower using their MesoMap system and historical weather data.

Wind Speed at 90 m

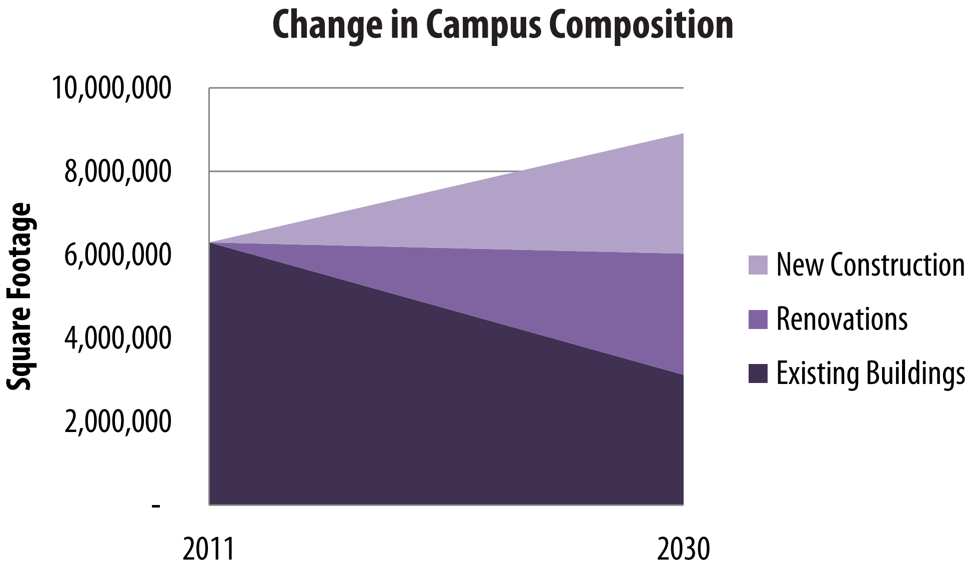
	m/s	mph
🟫	11.5 - 12.0	25.7 - 26.8
🟫	11.0 - 11.5	24.6 - 25.7
🟫	10.5 - 11.0	23.5 - 24.6
🟥	10.0 - 10.5	22.4 - 23.5
🟥	9.5 - 10.0	21.3 - 22.4
🟧	9.0 - 9.5	20.1 - 21.3
🟪	8.5 - 9.0	19.0 - 20.1
🟪	8.0 - 8.5	17.9 - 19.0
🟪	7.5 - 8.0	16.8 - 17.9
🟩	7.0 - 7.5	15.7 - 16.8
🟩	6.5 - 7.0	14.5 - 15.7
🟨	6.0 - 6.5	13.4 - 14.5
🟨	0.0 - 6.0	0.0 - 13.4

NATIONAL RENEWABLE ENERGY LABORATORY

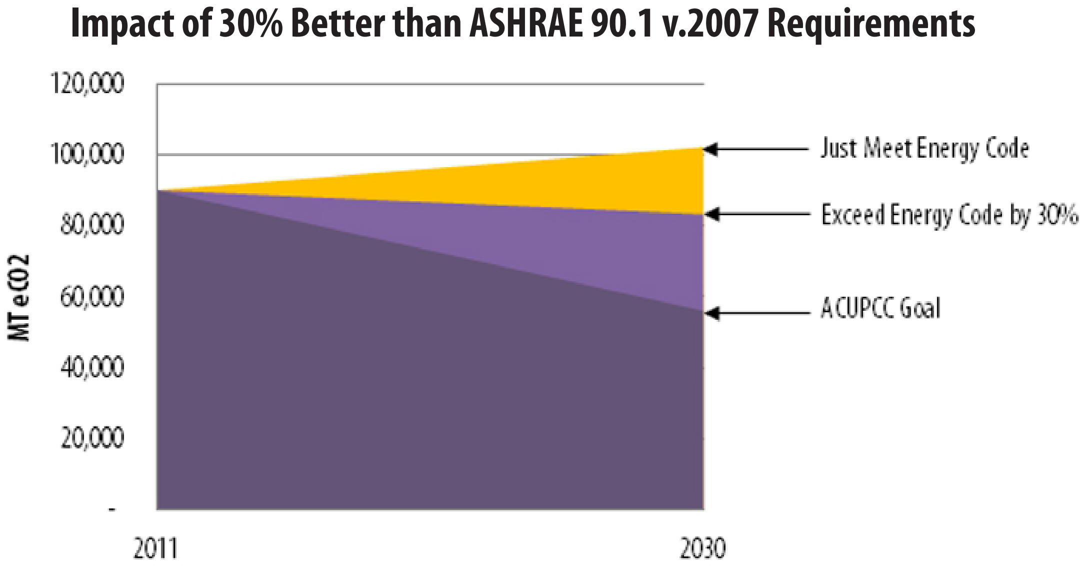
7. ENERGY CONSERVATION STRATEGIES FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS

Introduction

When the ECU Master Plan is fully implemented, nearly two-thirds of the campus (by size) will be comprised of buildings that have yet to be designed or will undergo a major renovation over the course of the master plan duration.   As a result, ensuring that these projects reach aggressive energy targets, can play a significant role towards meeting the ACUPCC target.



State-owned buildings must be designed, constructed, and certified to exceed the energy efficiency requirements of ASHRAE 90.1-2004 by 30% for new buildings, and 20% for major renovations. Since this policy was enacted by the State, North Carolina has adopted the 2007 version of ASHRAE 90.1.   Using a 30% reduction in energy use over ASHRAE 90.1 as an energy target, ECU could grow in size, while at the same time, reduce its GHG emissions.



Recommended Strategies for Reaching 30% Improvement over ASHRAE 90.1

Using the conceptual energy models that were created to understand the predicted energy use for each of the campus program types, fourteen strategies were evaluated to determine their viability and order of magnitude benefit for each of the program types. The GHG emissions reduction potential for each of the strategies was determined. Not every strategy is relevant or applicable to each program type. In some cases, modeling revealed little-to-no benefit of a specific strategy for a specific program type. The table below summarizes the fourteen energy conservation measures that were investigated, and the program types that revealed some GHG emissions reduction benefit associated with each strategy. The pages that follow the table describe the specific parameters for each strategy and summarize in more detail the emissions reduction potential for each approach.

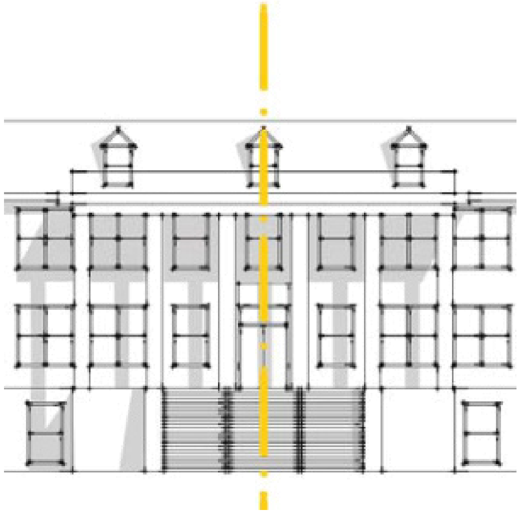
	Clinics	Labs	Dorms	Classrooms	Offices
New and Renovated Buildings					
1 Envelope Improvements	X	X	X	X	X
2 Rightsize Glazing	X	X	X	X	X
3 Glazing Improvements/Sunshading	X	X	X	X	X
4 High Performance Lighting	X	X	X	X	X
5 Daylighting and Lighting Controls	X	X	X	X	X
6 Energy Recovery	X	X	X	X	X
7 Demand Controlled Ventilation	X				X
8 Chilled Beams with Dedicated Outside Air				X	
9 Solar Domestic Hot Water	X		X		
10 Energy Efficient Equipment	X	X		X	X
11 Enthalpy Economizer vs. Fixed Dry Bulb	X			X	X
12 Unoccupied Setbacks for Lab Ventilation		X			
13 High Performance Fume Hoods		X			
14 Create Footcandle standards to prevent overlighting	X	X	X	X	X

Envelope Improvements

The energy code prescribes minimum insulation values for walls (R-12) and roofs (R-20.8). Exceeding these minimums for walls by 40% (R-20) and for roofs by 31% (R-30) was modeled to determine the impacts on energy use for each of the program types studied. The impact was very minor for program types whose energy use is dominated by internal loads and ventilation requirements (labs and clinics), but was more pronounced in program types whose energy use is more influenced by external loads (classrooms, offices, and dormitories). For future classrooms, offices, and dormitories, an envelope optimization study is recommended and the envelope performance targets described above should be pursued.

"Right Size" Glazing

In hot, humid climates like Greenville's, glazing should be carefully sized, recognizing the potential for creating unwanted heat gain during the cooling season. Also, since glass has a much lower thermal performance than wall, oversized glazing can compromise the thermal performance of the building during the heating season. Glazing should be sized to provide good daylight and views, to minimize reliance on artificial lighting and to provide occupants with a connection to the outdoors. Typically this goal can be achieved with a 30% window-to-wall ratio. The Master Plan describes a contextual architectural language that includes a recommended 35% window-to-wall ratio. Reducing the glazing ratio even slightly to 30% was shown to have a significant impact on program types whose energy use is more influenced by external loads (classrooms, offices, and dormitories). A high-performance building should not apply glazing uniformly across each of a building's elevations; instead the design should limit glazing on western elevations and south (unprotected) elevations, while favoring more glazing on the northern elevations (for daylighting) and for some program types, eastern glazing. Conceptual energy modeling is recommended for all future designs to right-size glazing.



High-Performance Glazing and Sun-Shading

Glazing is an important aesthetic and functional element for all buildings to provide natural daylight and views to the exterior, but with those benefits come two energy liabilities. First, code allows the thermal performance (R-value) of glazing to be only 16% of that required for an exterior wall, resulting in a weakening of a building's overall thermal performance when large amounts of glazing are used. Second, the code required shading coefficient of glazing results in a large amount of solar heat gain during summer months, driving up a building's cooling load. Glazing performance has significantly improved over the years to address these two potential liabilities. The thermal performance of glass can be improved by low emissivity (low-E) coatings and by infilling the cavity inside insulated glass units with inert gasses like argon. These technologies can improve the thermal performance of glass by 37.5%. Similarly the shading coefficient of glazing can be improved with coatings, like low-E coatings, silkscreen ceramic frit coatings, or reflective coatings, as well as by providing exterior sun shades on outside windows. Exterior sun-shades, even fixed exterior shades, can be designed to permit some solar gain in the winter months, while preventing solar gain during the summer months. Improving the shading coefficient of glass by 20% (above code-required minimums), which could be achieved by using a combination of a low-E coating and fixed horizontal sun-shades on all south facing windows, was evaluated and was shown to have a significant impact on program types whose energy use is more influenced by external loads (classrooms, offices, and dormitories). This approach had moderate benefits to even clinics and laboratories; as such, high-performance glazing is recommended for all future work on campus.

High-Performance Lighting

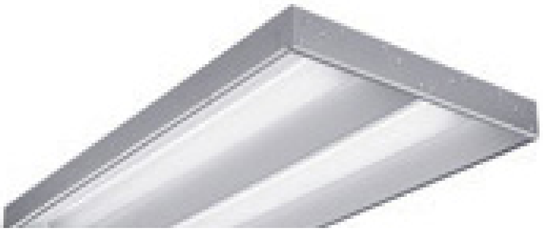
Code requires a maximum lighting power density (the amount of watts per square foot of building used for lighting) of for each program type. Improving upon this lighting power density (LPD) is possible, resulting in both less energy for lighting as well as less energy for cooling the waste heat from lighting. Strategies to improve LPD include task/ambient lighting (providing lower light levels that are supplemented as needed by task lights), high-efficiency lighting, and occupancy sensors that automatically shut off lights when spaces are not occupied. These approaches combined could result in a 25% reduction in LPD, a savings that was modeled to determine the potential total energy savings of this strategy. The results were significant, potentially resulting in a 4.11% reduction in the GHG emissions associated with all new work. These results were significant across all program types, and therefore it is recommended that a 25% reduction in LPD should be targeted for all future projects.

Daylighting

Reliance on artificial lighting can be significantly reduced by planning the building fenestration and interior layout so that daylight meets or supplements the building's lighting demand. Several design strategies should be considered to maximize the benefit of daylighting, including:

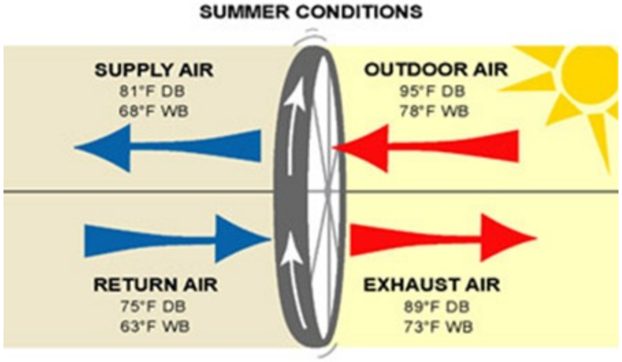
- Selection of glass to provide a good visible light transmittance, balanced with the need to control solar heat gain;
- Consideration of window location and size, with a preference towards windows with a head that touches the ceiling;
- Consideration of tall ceilings to allow daylight to penetrate deep within a building's footprint;
- Interior planning to avoid closed offices around a building's perimeter, allowing daylight to penetrate deep within a building's footprint;
- Preference for narrow building footprints to maximize daylight zones within the building footprint;
- Incorporation of light shelves (both interior and exterior) to improve daylight penetration;
- Use of light colored interior finishes, especially ceilings, to improve natural light reflection; and
- Automatic control of artificial lighting to dim or to step-down artificial light output depending on the amount of natural light entering the interior. Lighting zones and layouts should be planned to maximize the benefit from the natural light.

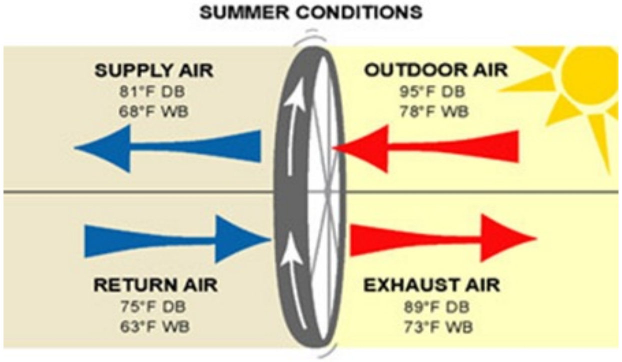
The potential energy savings for using daylight sensors for all perimeter spaces in combination with continuously dimmable artificial lighting was modeled. These results were significant across all program types, and therefore it is recommended that a daylighting and lighting controls should be targeted for all future projects.



Energy Recovery

Energy Recovery captures and transfers energy from the waste stream of one process to provide supplemental energy needed by another. Most commonly, these systems recover thermal energy from exhaust air -- a byproduct that's going to waste, recouping and recycling that energy, to pre-heat supply air. A total energy recovery wheel is an air-to-air heat exchanger that not only can transfer sensible heat but also latent heat. Not only is temperature transferred but these energy recovery wheels also transfer moisture using a desiccant. During the cooling season the desiccant wheel both dehumidifies and pre-cools outside air, significantly reducing the cooling requirements of the conditioned space. In the heating season, the process reverses and the energy recovery wheel both humidifies and preheats outdoor air.





Energy recovery wheels work best in program types with high ventilation rates, since these spaces have higher volumes of supply and exhaust air. Energy recovery wheels increase static pressures resulting in greater fan energy; as such, the savings in cooling and heating might be offset by increased fan energy in space types that do not have high ventilation rates. Modeling total energy recovery demonstrated significant energy benefits for the clinic and laboratory program types; modest benefits for classrooms; and little if any benefits for office space, so it is not recommended for a typical office space environment.

Demand Controlled Ventilation

Similar to the concept of an occupancy sensor that controls lighting based on whether a room is occupied, ventilation air can be supplied to a space only when it is occupied. Demand controlled ventilation uses CO_2 sensors to monitor interior air in order to sense when a space is occupied and to tailor ventilation rates based on the number of occupants within a space. Not only does this approach lead to energy savings, but it also can improve indoor air quality ensuring that adequate ventilation is always provided within a space. Concentrations of CO_2 from full occupancy of a space may take some time to build up, resulting in a potential lag between the time of occupancy and the time of increased ventilation. As such, demand controlled ventilation is better suited for spaces that do not experience significant, short term changes in occupancy, and therefore is not recommended for classrooms. Modeling showed energy benefits for demand controlled ventilation in both clinics and office spaces, especially in open office environments. As such, we recommend this approach is implemented in those two program types, or any others that have fluctuations in occupancy without lag time concerns.

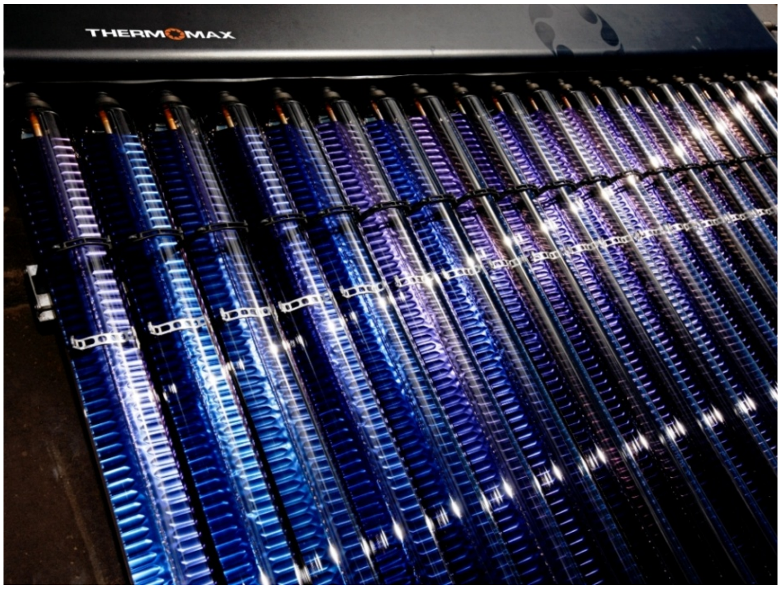
Chilled Beams with Dedicated Outside Air

Conventional, all-air HVAC systems rely on large air handling units and bulky ductwork to transfer heat to or from occupied spaces. Chilled beams distribute chilled water through overhead horizontal cooling coils, and milder water temperatures can be used reducing chiller demand. Chilled beams transfer heat primarily via piping, saving initial and operating costs while taking up less overhead space. "Passive" chilled beams and radiant ceilings/slabs largely rely on a downward convective force to distribute cooling from a coil or flat surface. "Active" chilled beams employ smaller primary air systems, often with a dedicated outside air system, to enhance air flow through a cooling coil to increase capacity and provide more uniform comfort within an area.

Since chilled beams use water as the heat transfer medium, and since water transports energy more efficiently than air, chilled beams can reduce chiller demand. Additionally, fans are only needed to supply the required ventilation air, since air is not used to heat or cool a space, resulting in significantly less fan energy. The energy savings from replacing a conventional VAV with reheat HVAC system with a chilled beam system was modeled for classrooms, laboratories, and office programs. The energy savings was noteworthy in classrooms; however the modeling did not reveal any savings in office an lab programs. Each of these program spaces were described only conceptually, and a more detailed energy model would need to be used to assess the viability of chilled beams for labs and office space. Often a hybrid between a chilled beam approach and a conventional VAV approach has merit. Ultimately an HVAC analysis should be conducted for each future project to assess the energy and life-cycle cost benefits comparing multiple HVAC approaches before selecting a system.

Solar Hot Water Heating

In lieu of using fossil fuels to heat hot water for domestic functions within a building, solar hot water units use copper pipes, painted black to absorb heat, wound back and forth within a flat plate collector covered with glass to prevent heat from escaping. Solar hot water heating is often supplemented with conventional water heaters for the occasional cloudy cold day when solar heating alone is not sufficient. Hot water provided by solar heating in combination with the campus steam system was modeled. It was assumed conservatively that the solar system would be adequate for domestic water heating for 60% of the year. This approach is well suited for program types with a large demand for domestic hot water, namely clinics and dormitories. For these program types, substantial energy savings were predicted.



Energy Efficient Equipment

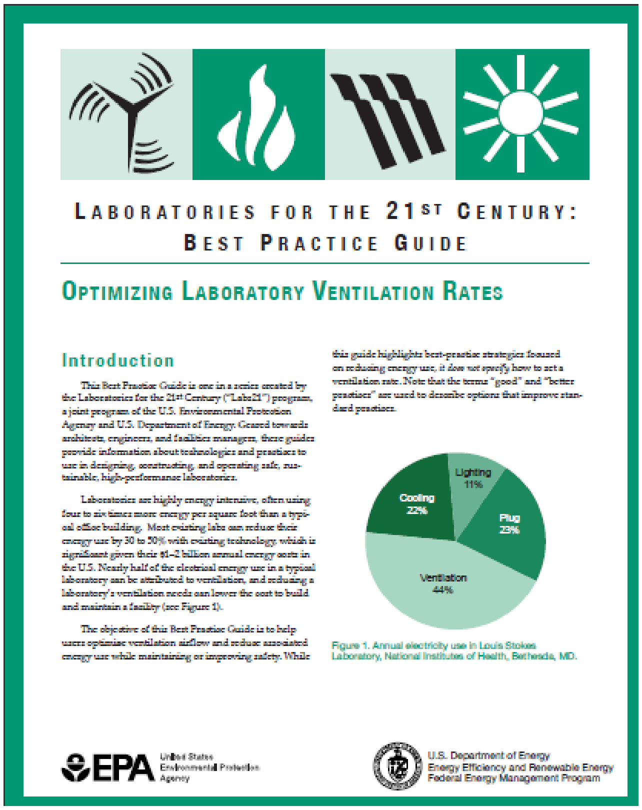
Plug loads, the amount of electricity needed to run equipment inside a building, are not regulated by code and can often represent a significant portion of a building's energy use. For the offices and classrooms, plug loads consist of the energy used to run computers, office equipment, audio-visual equipment, and vending/small kitchen equipment. Each of these elements is available with Energy Star labels. On average an Energy Star computer workstation use only two-thirds the energy of a conventional station. Similarly, an Energy Star rated vending machine consumes only 72% of the energy compared to a conventional vending machine. Conservatively, this study modeled a potential 20% reduction in plug loads for offices and classrooms achievable by using Energy Star equipment. Plug loads represent a significant portion of the energy use of laboratory and clinical programs as well. The opportunities for improving the energy efficiency of the laboratory and medical equipment are more limited. The Labs for the 21st Century (LABS21) program includes a database of energy efficient lab equipment: the "Energy Efficient Laboratory Equipment Wiki". A potential 10% reduction in plug loads, achievable by using energy-efficient equipment, was modeled for labs and clinics. Our modeling predicted significant savings, potentially resulting in a 4.81% reduction in the GHG emissions associated with all new work. These results were significant for all program types (except dormitories where there is limited opportunity to control plug loads), and therefore it is recommended that a plug load targets are established during the design of all future program types (except dormitories).

Enthalpy Economizer vs. Fixed Dry Bulb

A differential enthalpy economizer takes into account both temperature and humidity of air. Enthalpy is a measure of the total energy of air. An enthalpy economizer includes a control system that calculates the enthalpy of air using pairs of temperature and humidity sensors. Differential enthalpy will continuously compare the enthalpy of the air outside to the enthalpy of the return air. Whenever the air outside has a lower enthalpy, the unit will be in economizer mode. A fixed dry bulb approach will go into economizer cycle whenever outside air is below 65 degrees outside, even if it was 100% relative humidity (RH) and conversely will not go into economizer cycle if it is 70 degrees outside and 30% RH. Enthalpy economizers would compare the outside conditions with the return to select economizer cycle for the portions of the year where economizer cycle will yield energy savings. If it is 65 degrees and 100% RH, then return air would probably be the best choice. If it is 70 degrees and 30% RH outside, then economizer would be the best choice. Modeling was used to predict the energy savings of using enthalpy economizers in lieu of fixed dry bulb economizers for classrooms, offices, and clinics. It showed this approach will yield modest energy savings for each of those program types.

Unoccupied Setbacks for Lab Ventilation

Conventionally laboratory ventilation rates are derived from highly generalized guidelines, often selecting the highest value from a range without questioning the reasoning behind its value. Standard practice also approaches ventilation rates as constant values, without the ability to tailor rates to the occupancy. Excessive ventilation rates without the ability to setback ventilation when labs are unoccupied results in excessive energy use and an oversized, potentially wasteful HVAC system. A "more is better," approach to ventilation rates does not always increase safety. In fact, excessive ventilation can diminish safety conditions in labs that use hazardous and odorous materials, thus, best practices optimize rather than maximize ventilation.
The ASHRAE Laboratory Design Guide suggests that setback control strategies can be used in laboratories to reduce air changes hourly during unoccupied periods, e.g., at night and on weekends. The NFPA 45 Standard recommends a minimum ventilation rate of 4 air changes per hour (ACH) for unoccupied laboratories. Adding this setback to lab ventilation was modeled and found to have a substantial impact on laboratory energy use. Both optimization of lab ventilation and night-time setback to a ventilation rate of 4 ACH, is recommended for future laboratory projects.



LABORATORIES FOR THE 21ST CENTURY:
BEST PRACTICE GUIDE

OPTIMIZING LABORATORY VENTILATION RATES

Introduction

This Best Practice Guide is one in a series created by the Laboratories for the 21st Century ("Labs21") program, a joint program of the U.S. Environmental Protection Agency and U.S. Department of Energy. Geared towards architects, engineers, and facilities managers, these guides provide information about technologies and practices to use in designing, constructing, and operating safe, sustainable, high-performance laboratories.

Laboratories are highly energy intensive, often using four to six times more energy per square foot than a typical office building. Most existing labs can reduce their energy use by 30 to 50% with existing technology, which is significant given their $1–2 billion annual energy costs in the U.S. Nearly half of the electrical energy use in a typical laboratory can be attributed to ventilation, and reducing a laboratory's ventilation needs can lower the cost to build and maintain a facility (see Figure 1).

The objective of this Best Practice Guide is to help users optimize ventilation airflow and reduce associated energy use while maintaining or improving safety. While this guide highlights best-practice strategies focused on reducing energy use, it does not specify how to set a ventilation rate. Note that the terms "good" and "better practices" are used to describe options that improve standard practices.

Figure 1. Annual electricity use in Louis Stokes Laboratory, National Institutes of Health, Bethesda, MD.

EPA United States Environmental Protection Agency

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Federal Energy Management Program

*High Performance Fume Hood***s**

The average fume hood consumes more energy than three homes in an average U.S. climate (Mills, Sarter, 2003). A constant volume fume hood will exhaust a constant cubic feet per minute (CFM) of air regardless of the vertical sash position. As the sash is lowered additional bypass air is introduced to prevent face velocities from becoming too great, since high face velocities can result in hood contaminants spilling outside the hood, exposing lab workers to contaminants. A variable air volume fume hood is less energy intensive using a constant face velocity with little to no bypass air. The exhaust CFM is reduced as the sash is lowered while maintaining a fairly constant face velocity. Typically a Phoenix control valve is used to reduce the exhaust CFM as the sash is lowered. As the sash is raised the valve opens accommodating the increased fume hood exhaust in conjunction with an increase in supply air. High performance fume hoods are designed to operate with exhaust volumes as much as 50% less than Constant Volume fume hoods without compromising safety. They often use small supply fans located at the top and bottom of the hood's face, to push air into the hood creating a "curtain" of air at the sash. This helps prevent fumes from reaching a user standing in front of the hood and allows the exhaust fan to be operated at a much lower flow.

To predict the number of fume hoods that might occur in future laboratory buildings, the fume hood density from the existing campus was evaluated. These data suggested one fume hood per 4000 square feet of laboratory space. Based on the assumption that variable volume fume hoods would be the baseline in future lab buildings, the energy savings associated with using only high performance fume hoods for lab programs was modeled. Modeling the energy use of a VAV fume hood and a high performance fume hood demonstrates a 4' high-performance hood uses 47% less energy. This modeling conservatively assumes that laboratory exhaust is not fume hood driven and that the only energy savings is attributed to a reduction in exhaust fan energy (neither reheat nor ventilation). In fume hood intensive spaces, there may be additional energy savings. High performance fume hoods are recommended for all future laboratories.

Footcandle Standards to Prevent Over-Lighting

A "right sizing" approach can be applied to artificial lighting in University buildings, saving energy by not over-lighting spaces. Building codes describe minimum illumination levels, but often these levels are greatly exceeded. Some lighting designers simply provide 50 footcandles (fc) of light throughout a space. The Illuminating Engineering Society of North America (IESNA) sets suggested standards of foot-candle illumination in the United States. IESNA has professionally determined the amount of foot-candle illumination sufficient to perform tasks efficiently in specified spaces. ECU can create an illumination standard to provides both minimum and maximum footcandle levels for the spaces found on campus. Corridors can be designed to provide 10 fc, in lieu of the significantly higher levels found on campus. Classrooms can be designed for 30 fc, as opposed to the higher 50 fc often used. One good approach to lighting task-centered spaces is to provide reduced levels (20-30fc) for ambient lighting and supplement this with task lighting where needed. Even with using a task light, overall energy usage is greatly reduced. The High Performance Lighting measure recommended earlier in this study proposed a 25% reduction in lighting power density by using high-performance lighting to provide illumination efficiently. This current measure goes beyond that by also ensuring spaces are not overly lit, projecting additional lighting power density reductions as described below. The results were significant, potentially resulting in a further 5% reduction in the GHG emissions associated with all new work. These results were significant across all program types, and therefore it is recommended that a campus-wide lighting standard consistent with IESNA's minimum horizontal footcandles standards be pursued for all future projects.

	Baseline Value	Improved Value	Percentage Improved
Classroom	0.9	0.8	11.1%
Clinic	0.75	0.7	6.7%
Lab	0.9	0.8	11.1%
Office	0.75	0.7	6.7%
Residential	0.75	0.7	6.7%

Table X: Lighting Power Density targets for Program Spaces modeled to reflect Light Level Standards

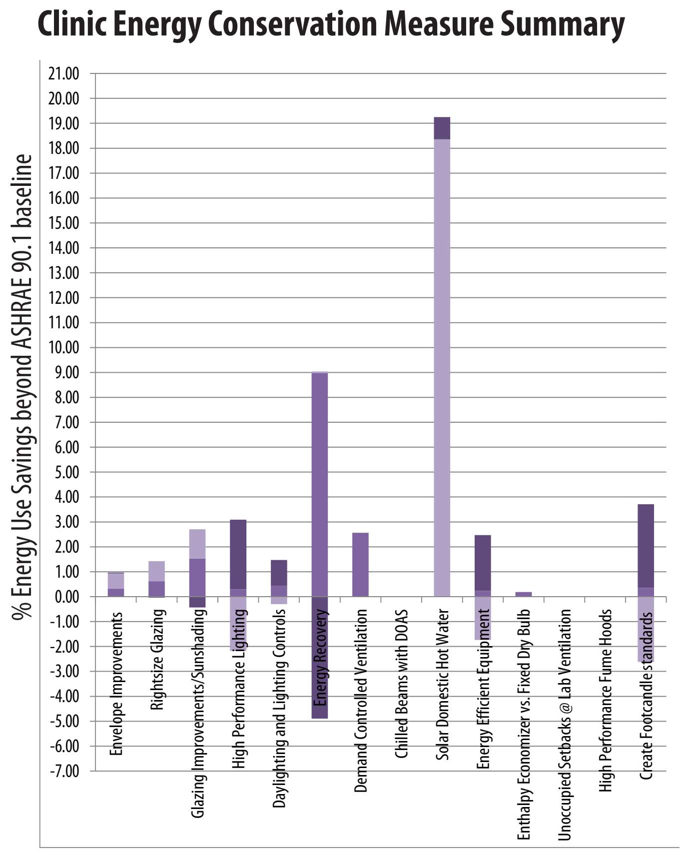
Summary of the Potential Energy Savings of Proposed Measures, by Program Type

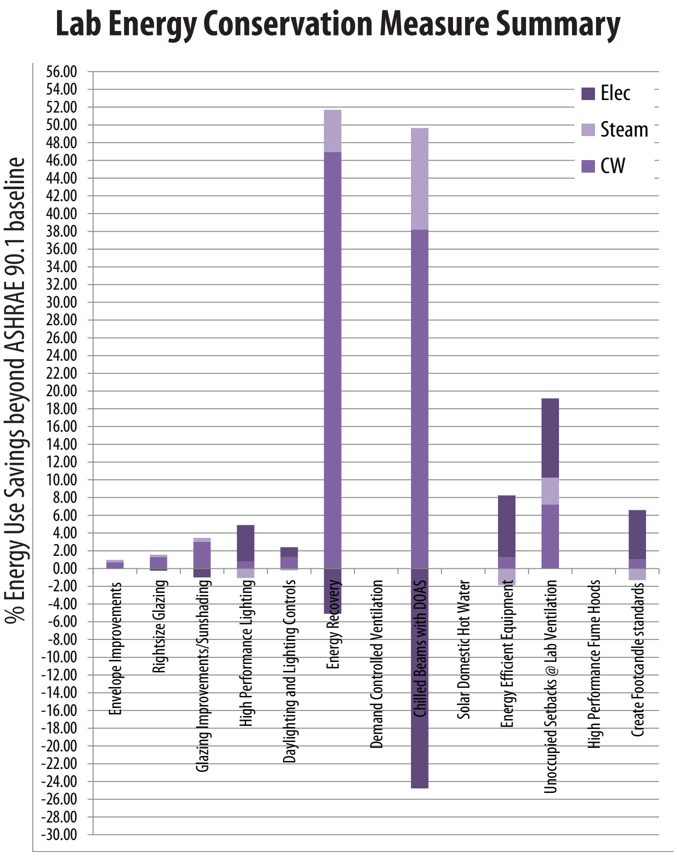
The energy modeling performed within this study is too conceptual to prescribe a specific path to achieving the targeted 30% reduction in energy use over the ASHRAE 90.1 v.2007 baseline, but it does demonstrate that this threshold is achievable without significant increases to capital budgets for new and renovated buildings. The simulation can also help prioritize, by program type, which measures have the most pronounced energy benefit.

Clinics can significantly reduce their energy use by incorporating solar domestic hot water systems to meet their predicted large hot water demand. Additionally, total energy recovery can be effective to minimize the energy penalty typically associated with the need for higher ventilation rates, effective at saving energy in both the heating and cooling season. High performance, effective lighting and energy-efficient medical equipment can also provide dramatic energy savings.

The most effective measures for laboratories center on the high ventilation rates found in this program type. Like clinics, total energy recovery is a very effective means of capturing both latent and sensible energy from the high volumes of exhaust air associated with labs' high air change requirements. HVAC systems like chilled beams, which decouple space conditioning from ventilation, were found to be very effective for this program type as well. Finally, right-sizing lab ventilation rates is another critical strategy to balance flexibility, safety, and energy efficiency in labs.

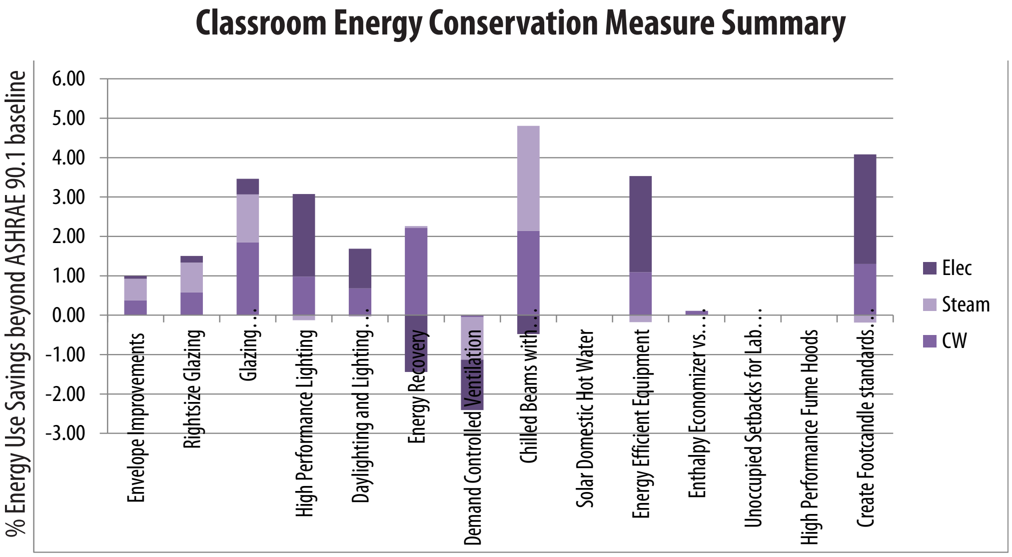
Energy simulation predicted that classrooms and office (administrative) program types benefit from measures that address the exterior envelope. Higher insulation levels, in addition to appropriate amounts of glazing coupled with exterior sun-shading, were found to provide significant opportunities for energy efficiency. Both program types benefitted from considerations to improve the effectiveness and

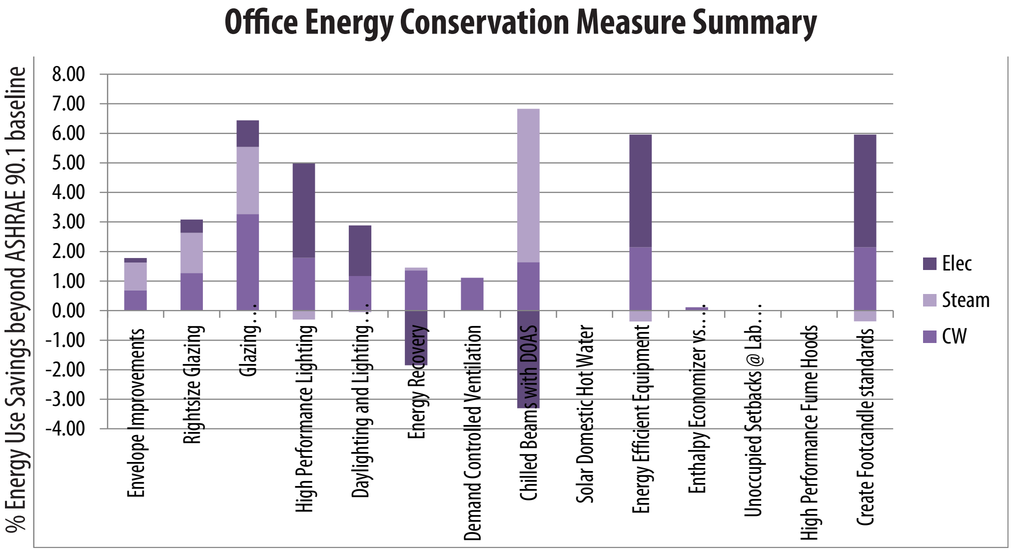

Clinic Energy Conservation Measure Summary

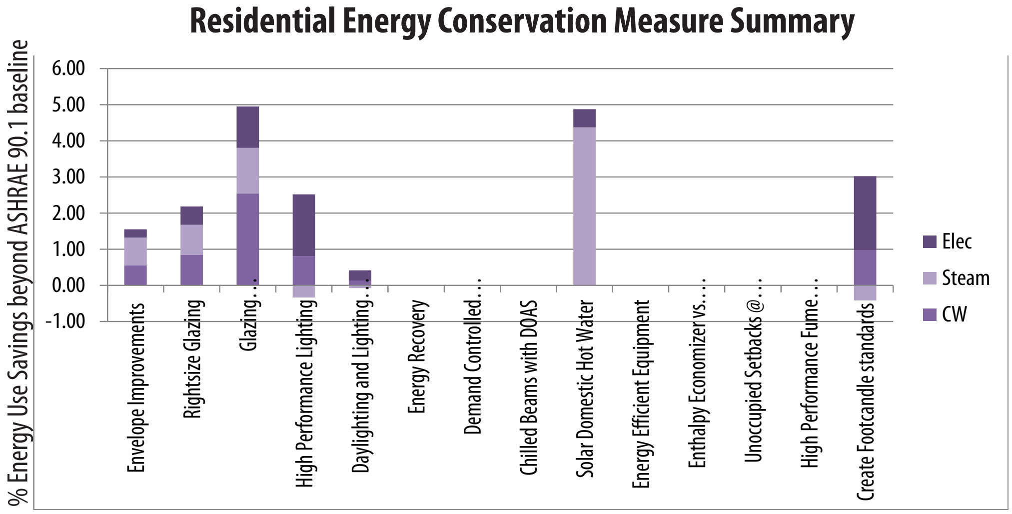

Lab Energy Conservation Measure Summary

efficiency of lighting. Methods to ensure spaces are not overly lit, as well as approaches that use lighting controls to integrate light levels with space occupancy and daylighting, yielded strong energy savings. Both program types should also place a priority on the selection of energy-efficient equipment, including energy star rated equipment, to reduce the intensive emissions associated with electricity consumption.

The energy use of dormitories, like classroom and office buildings, is largely impacted by the performance of the exterior envelope, and therefore high performance roofs, windows, and exterior walls should be a priority for this program type as well. Like clinics, dormitories have a large demand for hot water, so solar domestic hot water systems should be investigated for dorms as well. While solar hot water is most efficient in the summer months when dorms are partially or not occupied, they can still be an efficient and cost-effective strategy for the balance of the year as well. Lighting and electricity consumption in dorms can still be significant so high-efficiency lighting should be pursued. Additional dorm energy metering (and water metering) should be planned to encourage real time access into the energy use of individual dorm rooms to facilitate dorm energy (and water) competitions.


Classroom Energy Conservation Measure Summary


Office Energy Conservation Measure Summary


Residential Energy Conservation Measure Summary

8. ENERGY CONSERVATION STRATEGIES FOR THE EXISTING BUILDING STOCK

Introduction

Upon the full implementation of the Master Plan, nearly 46% of the make-up of the Main Campus and 37% of the make-up of the Health Sceince Campus will be comprised on existing buildings with no planned major renovations envisioned in the master plan. Upgrades to these buildings are difficult to fund, coming out of lean maintenance budgets or special funding streams. Retrofits and improvements to the existing campus have been continuously, although slowly, implemented over the past decade. The list below illustrates some additional projects that can more easily be funded, to continue the energy reduction trends seen in the annual energy consumption of the campus over the past few years.

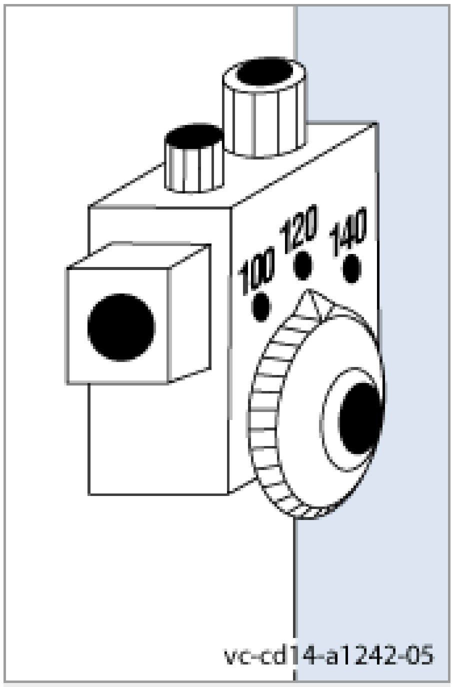
Existing Building Stock					
1 Setpoint Adjustments	X	X	X	X	X
2 Hotwater Adjustments	X		X		
3 Lighting Upgrades	X	X	X	X	X
4 Fumehood upgrades		X			
5 Unoccupied Setbacks for Lab Ventilation		X			
6 Dorm Competitions			X		
7 Add solar domestic hot water	X		X		
8 Retrofit Commissioning	X	X	X	X	X
9 Equipment Upgrades		X			X

Setpoint Adjustments

Recently, ECU adjusted the thermal set points used throughout the campus. The cooling setpoint went from 75 degrees to 76 degrees, and the heating set point went from 72 degrees to 68 degrees. While all new buildings modeled in the last section used these adjusted setpoints, the 2011 energy consumption data for existing buildings did not reflect the new setpoints, given the recentness of this change. By modeling campus building types using both the old and new setpoints, the GHG emissions savings from implementing this measure for all of the existing buildings that remain during the build out of the master plan, was predicted to be nearly 4%.

Hotwater Adjustments

Just as adjusting temperature standards for heating and cooling can yield significant energy savings, adjusting the temperatures of the domestic hot water can also yield savings. For this study, only dormitories and clinics were considered since these program types represent the majority of domestic hot water energy demand. With respect to hot water energy, approaches that reduce the amount of hot water used can have a dramatic impact on hot water energy. For dormitories, showers that use 1.7 Gallons per Minute (GPM) were recommended to reduce hot water energy, but ECU has already implemented this approach in all dormitories through a showerhead replacement project. Beyond that, research from the US Department of Energy has found that for each 10°F reduction in water temperature, one can save between 3%–5% in energy costs. Lowering hot water temperature is not recommended for clinics, given the need for hot water for infection control, but can be considered for dormitory water heaters. A 10°F reduction in water temperature was found to have a very minor impact (5 MT eCO_2) on campus GHG emissions.



Lighting Upgrades
ECU has embarked on an aggressive re-lamping project both throughout the Main and Health Sciences Campuses, replacing all incandescent lamps with compact fluorescents lamps, and replacing all T12 fluorescents lamps with T8 lamps. Additional savings can still be achieved. For spaces where footcandle levels are higher than what is needed, replacing conventional T8 lamps with more efficient, 25W super saver T8 lamps can reduce lighting energy by 22%. These lamps do not require modifications to the existing light fixtures and cost about $1.50 more per lamp, so the cost premium for this upgrade is relatively minor. This approach was modeled for 90% of all lamps in offices, clinics, and libraries; 80% of lamps in classrooms and dining halls; 50% of lamps in recreational facilities; and 30% of lamps in dormitories. For laboratories, light levels were assumed to be more critical, so a lamp replacement to a 25W super saver lamp was not pursued recognizing this replacement would reduce illumination levels by 20%, which might be detrimental to the research inside laboratories. Instead, these spaces might pursue a ballast and lamp replacement, swapping existing with more efficient ballasts allowing no reduction in illumination yet still resulting in a 7% reduction in lighting energy. This approach was modeled for all lamps in existing laboratories.

Most corridors throughout campus are lit to the same illumination levels that classrooms are lit to, or often light levels higher than the recommended illumination level of classrooms. Even acknowledging that some students use corridors as informal study areas, the recommended illumination of a lounge is one third that of a classroom. In addition to swapping out the corridor lamps with 28W super saver lamps, it is likely that removing ever other lamp in corridor lighting fixtures would still produce adequate illumination levels. This approach – delamping – can save the University both energy and money, using the savings to invest in the more efficient lamps. This approach was modeled for all corridors (assumed to be about 10% of overall lighting) in recreational, dining, classroom, clinic, library, and office building types. Lighting controls can also significantly reduce lighting energy. Occupancy sensors are recommended for small, single occupant spaces that are not continuously occupied throughout the day. An occupancy sensor (dual technology) can replace an existing wall switch at a cost of $100 per new switch. Conservatively, we assumed a 10% reduction in lighting energy for all spaces with lighting control changed to occupancy sensors. This approach assumed that 40% of spaces in classrooms, clinics, libraries, offices could be upgraded, and 20% of spaces in laboratories could be upgraded to occupancy sensor light controls. For large spaces like those found in recreational facilities and dining halls, time clocks, which automatically control lighting around a regular schedule, are recommended. Our model assumed 40% of spaces in these program types could achieve a 10% reduction in lighting energy.

For dormitories, additional lighting energy reductions can be achieved by banning incandescent lamps in student dorm rooms, or having a program to provide compact fluorescent lamps to students to encourage their use. ECU has already begun this program. This approach was modeled for 30% of the lighting in dormitories, assuming CFL's use about one third the energy of a conventional incandescent lamp. For warehouse spaces, lighting energy savings are best achieved by complete re-lighting projects. These might pursue LED or fluorescents lamps in lieu of metal halide lamps, so that lighting is provided only at the spaces that need to be lit, rather than providing broad ambient lighting. Conservatively, a 10% reduction in lighting energy at warehouses can be achieved.

The sum of all of these lighting upgrades can substantially add up. Modeling predicted a 5.5% reduction in GHG emissions of the existing buildings that remain during the build out of the master plan – a savings of 2,274 MT eCO_2 each year.

*Fume hood upgrade*s

Fume hoods limit a person's exposure to hazardous fumes by using a fan that draws air from the front of the cabinet, containing fumes to within the cabinet, and then exhausts that air outside the building. The Main Campus has 101 active Variable Air Volume (VAV) fume hoods and 39 active Constant Air Volume (CAV) fume hoods. The Health Science Campus has 31 VAV fume hoods and 102 CAV fume hoods. A CAV fume hood will exhaust a constant cubic feet per minute (CFM) of air regardless of the vertical sash position. As the sash is lowered additional bypass air is introduced to prevent face velocities from becoming too great, since high face velocities can result in hood contaminants spilling outside the hood, exposing lab workers to contaminants. A VAV fume hood is less energy intensive using a constant face velocity with little to no bypass air. The exhaust CFM is reduced as the sash is lowered while maintaining a fairly constant face velocity. Typically a Phoenix control valve is used to reduce the exhaust CFM as the sash is lowered. As the sash is raised the valve opens accommodating the increased fume hood exhaust in conjunction with an increase in supply air.

High performance fume hoods are designed to operate with exhaust volumes as much as 50% less than Constant Volume fume hoods without compromising safety. They often use small supply fans located at the top and bottom of the hood's face, to push air into the hood creating a "curtain" of air at the sash. This helps prevent fumes from reaching a user standing in front of the hood and allows the exhaust fan to be operated at a much lower flow.

Modeling the energy use of a CAV fume hood, a VAV fume hood, and a high performance fume hood, demonstrated that a high-performance fume hoods uses 57.5% less energy than a CAV fume hood and 32% less energy than a VAV fume hood. This modeling conservatively assumes that laboratory exhaust is not fume hood driven and that the only energy savings is attributed to a reduction in exhaust fan energy (neither reheat nor ventilation). In fume hood intensive spaces, there may be additional energy savings. Nearly 80% of the fume hoods on campus are within the Science & Technology Building, the Howell Science Building, and the Brody Medical Science Building. Each of these buildings is slated to be renovated within the master plan. Replacing all remaining, existing fume hoods with high performance fume hoods could result in a 0.27% reduction in GHG emissions of the existing buildings that remain upon the build out of the master plan – a savings of 112 MT eCO_2 each year.

Unoccupied Setbacks for Lab Ventilation

Ventilation rates in campus laboratories have followed a "more is better," approach giving users an increased perception of safety. In fact, excessive ventilation can diminish safety conditions in labs that use hazardous and odorous materials, thus, best practices optimize rather than maximize ventilation. Standard practice also approach ventilation rates as constant values, without the ability to tailor rates to the occupancy. Excessive ventilation rates without the ability to setback ventilation when labs are unoccupied results in excessive energy use and an oversized, potentially wasteful HVAC system.

The ASHRAE Laboratory Design Guide suggests that setback control strategies can be used in laboratories to reduce air changes hourly during unoccupied periods, e.g., at night and on weekends. The NFPA 45 Standard recommends a minimum ventilation rate of 4 air changes per hour (ACH) for unoccupied laboratories. Adding this setback to lab ventilation was modeled and found to have a substantial impact on laboratory energy use. Still very few laboratories will remain (un-renovated) upon completion of the master plan, so the impacts of this change are fairly small. Given that, modeling this measure for the small number of laboratories that remain upon the build out of the master plan predicted a savings of 9 MT eCO_2 each year.

Dorm Competitions

Dorm competitions have been used at campuses across the country to raise awareness in energy conservation, reduce campus energy use, and tap into friendly competition to build campus spirit. Competitions can meter energy use within a dorm as a whole (pitting dorm against another dorm), or per floor (pitting floor against floor), or per individual dorm room (pitting each room or suite against others within the same dorm). It is the competition itself that yields energy savings, often substantial savings. A recent dorm competition at Notre Dame awarded first place to the dorm that used 18.6% less energy, and second place to the dorm that used 12.6% less energy. The winning dormitory at UCLA's dorm competition used 30% less energy, and the average savings was 10%. ECU has successfully begun dorm competitions, and has started one at the beginning of the Fall 2012 semester. ECU should document the results to help validate the energy savings from these events.

252,007 kilowatt-hours from Sep 12 to Oct 12

SOUTH	33,275 kWh
NORTH	27,387 kWh
DASCOMB	22,123 kWh
BURTON	21,384 kWh
EAST	21,164 kWh
FIRELANDS	18,076 kWh
KAHN	13,043 kWh
BARROWS	11,801 kWh

An energy dashboard display from Oberlin's dorm competition

Our team modeled the results of dorm competitions assuming that they would reduce dormitory energy use by 10% on average. Modeling predicted a 3.86% reduction in GHG emissions of the existing buildings that remain during the build out of the master plan – a savings of 1,592 MT eCO_2 each year.

Add solar domestic hot water

Using data from CBECS, domestic hot water represents 31.46 KBTU/sf/year of dormitory energy consumption and 4.7246 KBTU/sf/year of clinic energy consumption. Using that average water consumption data, solar domestic hot water has the potential to eliminate over 40,000,000 KBTU/year. In late 2011, ECU received a proposal from SolTherm, a solar energy provider located in North Carolina. SolTherm would design, install and maintain the system at ECU to provide 60% of ECU's domestic hot water needs; and in exchange, ECU would purchase the hot water from SolTherm at a fixed energy rate (reported to be an overall savings of 1% compared to ECU's current energy rate) for the duration of the service agreement. These power purchase agreements are a means of purchasing green energy, while funding on-campus renewable energy projects.

Our team modeled the results of implementing such an agreement to provide for 60% of ECU's hot water demand. Modeling predicted just over a 4% reduction in GHG emissions of the existing buildings that remain during the build out of the master plan – a savings of 1,665 MT eCO_2 each year.

Retrofit Commissioning

Retrofit Commissioning (RCx)is a systematic process to improve an existing building's performance by identifying operational improvements that will increase occupant comfort and save energy. Buildings, even recent ones and ones that were originally commissioned, may not have systems programmed properly for current operations. Many factors can contribute to building systems going out of sync. Building automation systems are often changed or circumvented. For example, when controls are altered because work hours change or to accommodate an after-hours event, often those controls don't get changed back. Additionally, over time, some things may go out of calibration causing a building's controls to get further and further away from the design intent. RCx can bring the building back to its originally designed optimal performance.

Typical energy savings are between 5%-20% often with paybacks of less than one year, according to the Portland Energy Conservation Inc. (PECI), an authority on Commissioning. According to a 2005 study called "The Cost-Effectiveness of Commissioning New and Existing Commercial Buildings: Lessons from 224 Buildings," (Lawrence Berkeley National Laboratory, PECI and the Energy Systems Laboratory at Texas A&M University) median payback for retro-commissioning was 8.5 months. The study also showed the average energy savings of the 224 buildings to be 15%. Intuitively, the payback was quicker in energy intensive buildings like laboratories and hospitals, and slower in small projects.

For the purposes of this study, we assumed that over the next 18 years, ECU will retrofit-commission one in every five buildings that are projected to remain un-renovated in the master plan. This modest pace was established in recognition of the challenges in funding the upfront costs associated with retrofit-commissioning, despite the very quick payback. ECU is beginning to retrofit commission an existing campus building and will use that experience to pilot and better justify more future retrofit commissioning projects. Modeling 20% of existing building stock each achieving an average of a 15% reduction in energy use through retrofit-commissioning predicted just over a 3% reduction in GHG emissions of the existing buildings that remain during the build out of the master plan – a savings of 1,238 MT eCO_2 each year. RCx has a very big potential for greenhouse gas reduction at ECU and at the same time, has one of the quickest paybacks – less than one year on average. By extending RCx to all of the existing campus buildings to remain unrenovated, ECU can significantly decrease their GHG emissions.

Equipment Upgrades

Plug loads, the amount of electricity needed to run equipment inside a building, often represent a significant portion of a building's energy use. For the offices and classrooms, plug loads consist of the energy used to run computers, office equipment, audio-visual equipment, and vending/small kitchen equipment. Each of these elements is available with Energy Star labels. On average an Energy Star computer workstation use only two-thirds the energy of a conventional station. Similarly, an Energy Star rated vending machine consumes only 72% of the energy compared to a conventional vending machine. Conservatively, this study modeled a potential 20% reduction in plug loads for offices and classrooms achievable by purchasing Energy Star equipment when equipment needs replacement.

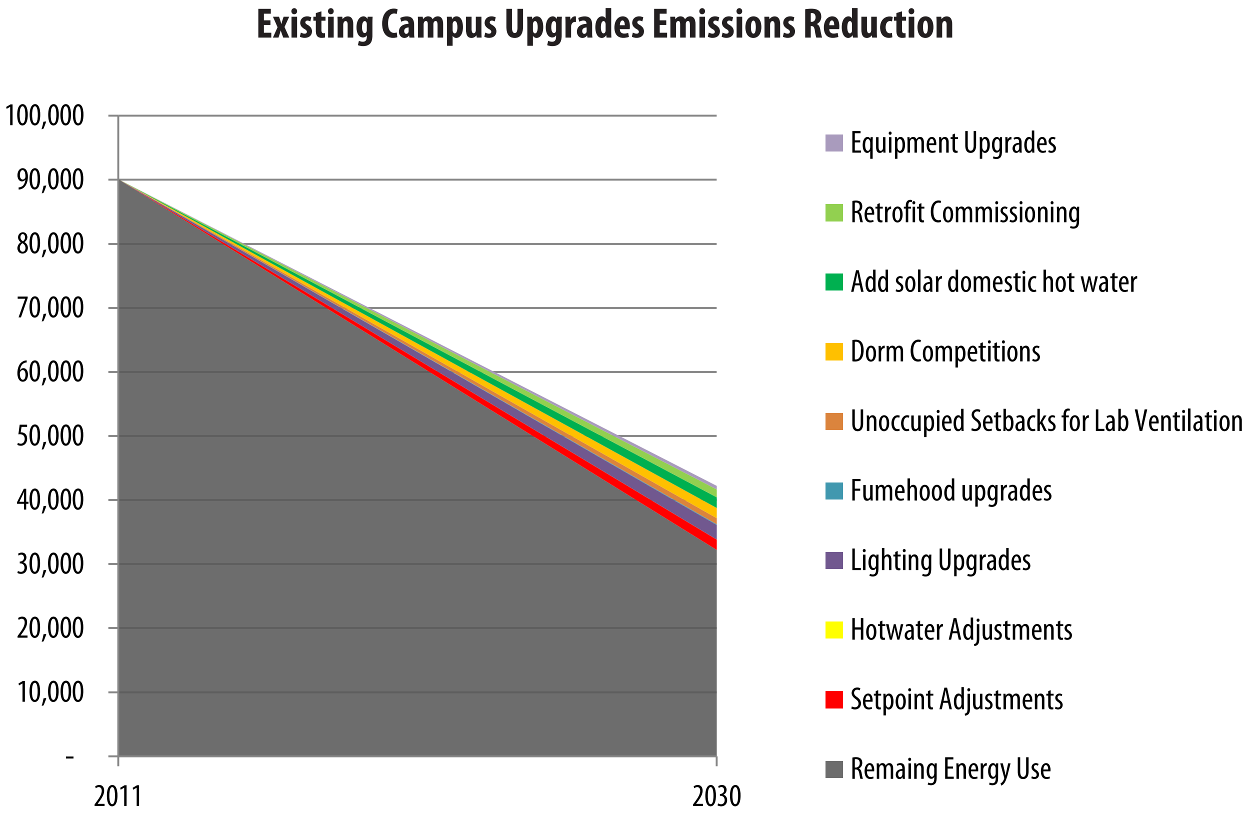
Dining Hall (commercial kitchen) equipment is also a major source of energy use on campus, and high-efficiency restaurant equipment is increasingly available. The table on the next page illustrates the energy costs of standard and energy-efficiency alternatives to commercial kitchen equipment An equipment upgrade of campus dining halls could easily yield a 20% reduction in plug load energy use. Modeling a 20% reduction in plug loads for all existing remaining classrooms, office spaces, and dining halls predicted a 1.33% reduction in GHG emissions of the existing buildings that remain during the build out of the master plan – a savings of 548 MT eCO_2 each year. These savings are conservative, and additional emissions reductions are likely, depending on the scope of the equipment upgrades.

Table 1. Full Service Restaurants--Standard vs. Energy Efficient Product Savings Estimates

Technology	Standard Equipment and Use ($/yr)	Energy Efficient Equipment and Use ($/yr)	Savings ($/yr)	Energy Savings (%)
Solid Reach-in Refrigerator	210	97	113	54
Under-counter Refrigerator	146	124	22	15
Lighting – Incandescent	26	7	20	75
Lighting – Fluorescent	34	25	9	26
Solid Reach-in Freezer	432	281	151	35
Walk-in Freezer/Cooler	118	39	80	67
Hot-Food Holding Cabinet	767	438	329	43
Fryer	1,169	806	364	31
Steamer	2,700	508	2,191	73
Under-counter Freezer	228	196	32	14
Glass Reach-in Refrigerator	325	163	162	50
Convection Oven	1,051	731	320	30
Prep Table	406	182	223	55
Toaster	964	128	836	87
Broiler	3,539	2,882	657	19
Hot Water Heater	11,354	10,358	996	15
Combination Oven	4,163	2,596	1,567	39
Pre-rinse sprayer	1,973	1,052	921	47
Ware washer	7,657	6,432	1,226	34
Ice Machine	3,650	2,940	710	20
Demand Control Exhaust Hood	7,500	5,000	2,500	33
Griddle	1,117	1,056	61	5

Summary of the Potential Energy Savings of Existing Building Measures

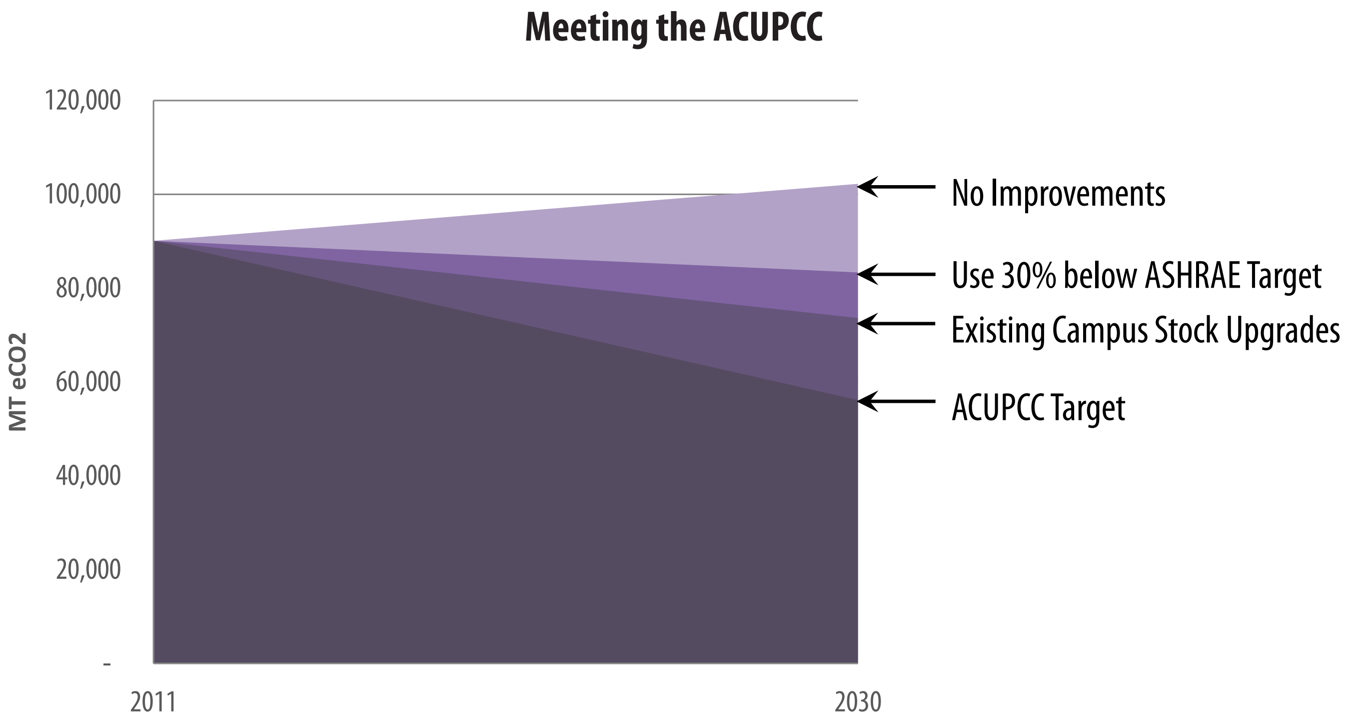
The wedge diagram below illustrates the relative impact of each of the nine conservation measures described in this last section. Some approaches, like hotwater adjustments, were found to have minimal impacts on the campus GHG emissions, while others were predicted to have a substantial benefit. The biggest improvement was found to be in lighting upgrades, building on the aggressive lighting upgrades that ECU has embarked on over the past few years. Lighting upgrades are cost effective and can be implemented incrementally. Set point adjustments are also significant. Since these measures have already begun to be implemented, one would expect to see a reduction in GHG emissions once 2012 energy use is reported, and normalized for changes in campus size and impacts from actual (not predicted) climate. Finally the solar domestic hot water measure was found to play a relatively high role in measures to reduce emissions from the existing building stock that remains. Through an agreement with a renewable energy provider, similar to a power-purchase agreement except in this case for purchased hot water, this strategy can be implemented without an upfront investment in solar infrastructure.



By the year 2030, the total ECU campus GHG emissions, predicting planned new and renovated buildings will achieve a 30% improvement over the energy code, was estimated to be 83,360 MT eCO_2. If all of the GHG emissions reduction measures described in this last section were implemented, campus GHG emissions could be reduced by additional 9,668 MT eCO_2. This reduction would alter the total campus GHG emissions to be 73,692 MT eCO2. Since the ACUPCC emissions reductions target is 56,162 MT eCO_2, an additional 17,481 MT of GHG emissions reduction is still needed to meet the ACUPCC GHG target by year 2030. This balance of 17,481 MT eCO_2 could be met, in part, through more aggressive retrofits to the existing campus.

This study assumed a modest implementation of retrofit commissioning. Since retrofit commissioning can result in significant energy savings with a very quick return on investment, it may be possible to fund more widespread retrofit commissioning projects on more of the remaining building stock, using the savings from past projects to fund future projects. It may be possible to reduce campus GHG emissions by nearly another 5000 MT eCO_2 by using retrofit commissioning on the entire remaining campus building stock. Other potential means of decreasing GHG emissions from the existing buildings that remain would be to expand the purchased solar domestic hotwater above the 60% threshold currently modeled. Additionally, but 2030, future technologies may reveal even greater opportunities for retrofitting the existing campus.

Having targeted future campus buildings, future campus renovations, and retrofits to the existing campus building stock, there is one final opportunity to reduce campus emissions: improvements to the campus chilled water and steam plants and supporting infrastructure, including embracing renewable energy sources.



9. INFRASTRUCTURE ENERGY SAVING MEASURES

Recommended Strategies for Plant and Infrastructure

A range of energy saving and GHG emissions reduction measures were evaluated for the thermal utility infrastructure for both the Main and the Health Science Campuses. These measures were considered for both the steam and chilled water generation facilities. Each measure was evaluated on its potential energy reduction capability, estimated construction cost, and potential economic payback.

Variable Frequency Driven Chiller

Variable frequency drives (VFDs) for electric motor-driven chillers offer energy savings in the form of reduced motor power consumption at part-load conditions, as compared to non-VFD driven chillers. This energy saving measure provides benefit in most situations where chillers are subject to varying load conditions, rather than a full-capacity, base-loaded condition. For the scope of this study, VFD-driven chillers were considered for addition to the existing Main Campus CCP-1 chiller plant when campus chilled water demand increases beyond existing capacity. In this situation the new VFD-driven chiller would be staged on first and staged off last, thus allowing it to operate the most number of part-load hours. Evaluation of such an addition reveals a 5% (1,422 MMBTU/Yr) annual energy savings compared to a non-VFD driven chiller, as well as a 15% return on investment. Therefore, it is recommended the next chiller added to chiller plant CCP-1 be VFD-driven. Additionally, the energy saving results of this particular situation, accompanied by the ever-decreasing cost of VFD-driven chillers, suggests the recommendation for selection of VFD-driven chillers for all future chiller additions or replacements and central chiller plant constructions on both the Main and Health Science Campuses.

Feedwater and Condensing Economizers

In process of generating high pressure steam, nearly 16.5% of the energy input to the boiler is wasted due to inefficiencies and nearly 90% of that energy is lost in the flue gas exhausted from the boiler. The potential exists to utilize feedwater and condensing economizers to capture heat energy contained in the flue gas exhausted from the boiler, thus improving overall boiler efficiency and reducing the amount of fuel required for operation. Feedwater economizers utilize boiler exhaust gas to pre-heat incoming boiler water, thus reducing the amount of fuel energy required to generate steam. Condensing economizers are typically utilized to heat a source of low-temperature water such as domestic water, condensate, or boiler makeup water. The condensing naming of the economizer refers to the ability to condense water vapor contained in the boiler exhaust gas, which allows the condensing economizer to capture heat energy the feedwater economizer is not capable of removing. Feedwater and condensing economizers are both heat exchanger appliances that can be retrofitted into the existing exhaust gas stacks of the boilers at the steam plants for both the Main and Health Science Campuses. Physical construction and arrangement of economizers vary with each situation and manufacturer, and some manufacturers offer feedwater and condensing economizers constructed in the same physical package. For this energy savings measured, feedwater and condensing economizer were considered for addition to the existing boilers of both campuses. At the Main Campus steam plant, the existing 40 KPPH boiler is already equipped with a feedwater economizer. Analysis revealed the most economically justifiable measure is to add a feedwater economizer to only one of the 75 KPPH boilers, (rather than all three of the 75 KPPH boilers) and install a common condensing economizer to pre-heat condensate. This measure yields a 4.3% (18,000 DKTHM/Yr) annual energy savings compared to the existing installation. At the Health Science Campus steam plant, evaluation suggested the addition of a combination feedwater and condensing economizer for heating boiler water and condensate respectively to each of the existing boilers yields a 5.2% (7,000 DKTHM/Yr) annual energy savings compared to the existing installation. The low capital investment required and energy savings obtained from the addition of feedwater and condensing economizers makes their retrofit to the existing steam plants a justifiable recommendation.

Continuous Blowdown Heat Recovery

Another source of energy waste in the generation of high pressure steam is the heat loss incurred due to continuous boiler blowdown (CBD), which is required to maintain proper boiler water chemistry. Currently, CBD at both the Main and Health Science Campus steam plants is wasted to drain and no attempt is made to recover the heat energy contained in the wasted water. Through use of a specialized continuous blowdown heat exchanger, makeup water required for the steam plant can be preheated by the wasted CBD, thus reducing energy waste and improving overall boiler efficiency. The addition of a CBD heat exchanger at the Main Campus boiler plant has the potential to save 0.7% (3,000 DKTHM/Yr) in annual energy savings. At the Health Science Campus the addition of a CBD heat exchanger has the potential to save 0.6% (1,000 DKTHM/Yr) in annual energy consumption. CBD heat exchangers have a very low capital investment compared to other boiler room equipment and can easily be integrated into the existing steam plant operation, and thus are recommended for achieving energy savings at both campus steam plants.

Oxygen Trim

Boilers are by no means maintenance-free equipment. One annual maintenance routine required for every boiler is a combustion tuning to ensure the burner is providing the correct ratio of fuel and air for proper combustion. But despite the accuracy of that tuning, it cannot compensate for air temperature and humidity changes, as well as changes in the energy content of fuel, which occur throughout the year until the next tuning. Oxygen trim control provides a continuous, on-the-fly adjustment of fuel-to-air ratio to ensure the most efficient and safe boiler operation. Oxygen trim can easily be integrated into existing burner systems, and only require the addition of an oxygen sensing probe to the flue gas exhaust stack, possible damper actuator to the burner air intake, and small programming modifications. Overall capital cost is relatively small. The Main Campus steam plant is already equipped with oxygen trim control and is already taking advantage of this energy savings measure. However the boilers at the Health Science Campus steam plant are not equipped with oxygen trim control. The addition of oxygen trim control has the potential to save 0.5% (650 DKTHM/Yr) in annual energy consumption and is recommended for installation at the Health Science Campus.

Steam System Distribution Losses

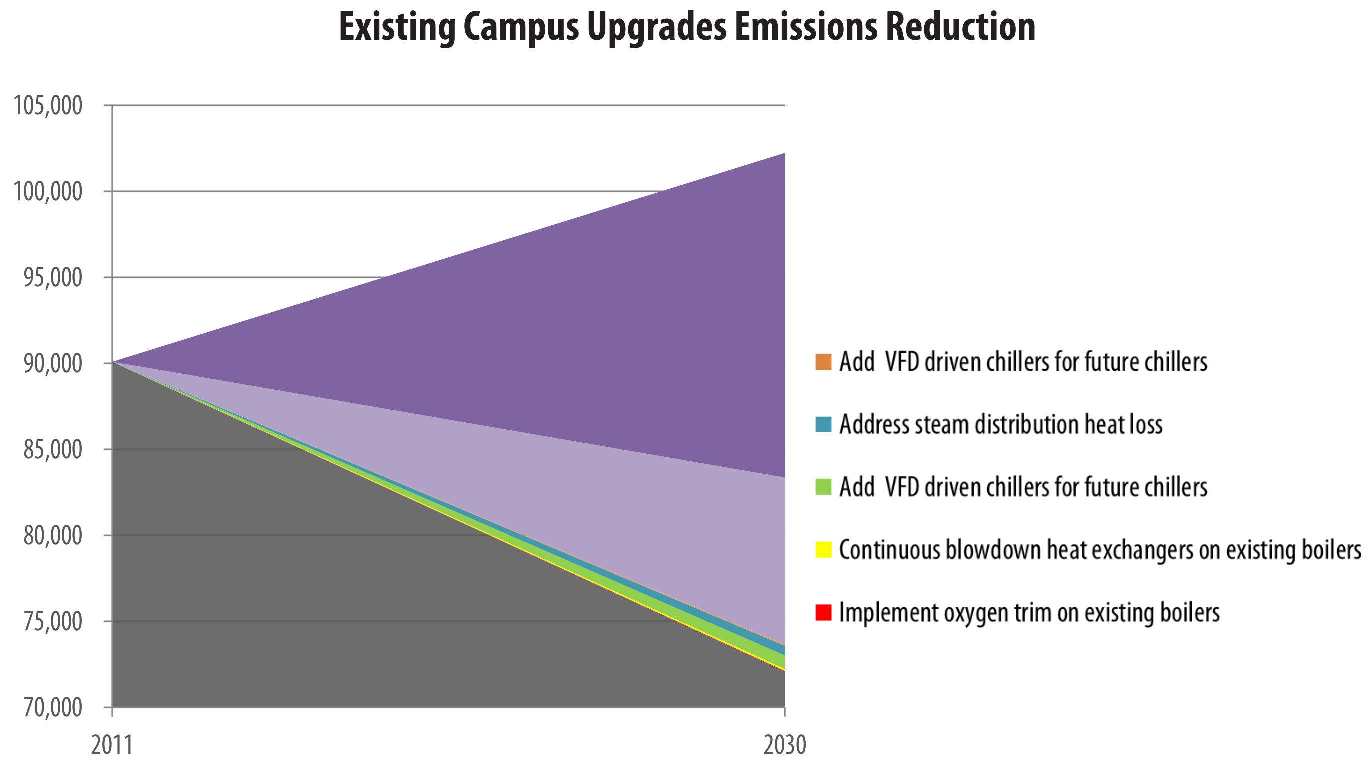
Steam systems are notorious for thermal energy loss. The high operating temperatures relative to the ambient air and ground conditions lend itself to high radiation and conduction losses. These losses are further exaggerated by failed piping insulation caused by water intrusion into tunnels, manholes, and direct-buried conduit systems. In addition pipe and valve leaks, as well as trap failures further lend to the thermal energy loss incurred. Evaluation of the existing steam distribution networks revealed an approximate 16% (41,000 MMBTU/Yr) loss of total steam energy distributed on the Main Campus, while the Health Science Campus distribution network has an approximate 6.5% (5,300 MMBTU/Yr) loss of total steam energy distributed. Improving the thermal energy loss of steam distribution systems is no easy task- especially for direct-buried type systems. It is impossible to replace failed insulation in direct-buried type systems, and total pipe system replacement involves a considerable capital investment and is often difficult to coordinate with other utilities in the area. Tunnel and manhole piping more easily lends itself to insulation replacement, but instances do exist where even those types of piping present significant challenges. While it may not be possible to completely prevent the thermal energy loss from steam distribution systems, there are small maintenance task that can be performed to reduce the amount of energy lost. It is estimated by repairing insulation in tunnels and manholes where it has failed, repairing failed-open steam traps, and correcting piping and valve leaks the steam distribution loss may be reduced by approximately 5% (13,000 MMBTU/Yr) on the Main Campus and by approximately 1.5% (1,200 MMBTU/Yr) on the Health Science Campus. It is recommended an ongoing, systematic maintenance program be created to identify steam distribution system losses to ensure the highest level of energy is saved.

Cogeneration

It is possible to improve the overall efficiency of both electric power production and thermal energy generation through the use of cogeneration. Generally this process utilizes a combustion turbine to drive an electric generator, and the high temperature exhaust gases from the turbine are passed through a heat recovery boiler to produce steam. Thus, simultaneous generation of power and heat is achieved. Generally the best economics for such a system are achieved by operating the system year round. This means the steam generating capabilities of the system must be matched to the steam demand of the campus environment it serves. The capital cost incurred for such a generating system run in excess of $3,000/kW, and systems are available in the size range of 1.2 to 22 MW power production with capability of producing 8 PPH of steam per kW of power produced. The Main Campus environment is the most likely candidate for a cogeneration system, with a minimum campus steam demand of 21,000 PPH. Installed system costs for possible system run approximately $4.3 million for 1.2 MW power production and 8 KPPH steam production, to $15 million for 4.6 MW power production and 13.8 KPPH steam production. Any possible cogeneration system sized for the Main Campus has a simple payback of in excess of 24 years- nearly identical to the expected life the of the system. Because of the significant capital expenditure involved and the lack of an attractive payback, cogeneration is not recommended as an energy saving measure.

Summary of the Potential Plant and Infrastructure Measures

The wedge diagram below illustrates the relative impact of each of the recommended conservation measures (excluding cogeneration) described in this last section. Compared to the previous wedge diagrams, the opportunities for reducing emissions through plant and infrastructure improvements are relatively minimal. The combined reduction of all five plant improvement strategies yields a total GHG emissions reduction of just over 1,560 MT eCO2. A shortfall of 15,920 MT eCO2 remains.



10. USING RENEWABLE ENERGY TO BRIDGE THE GAP

Options for Renewable Energy

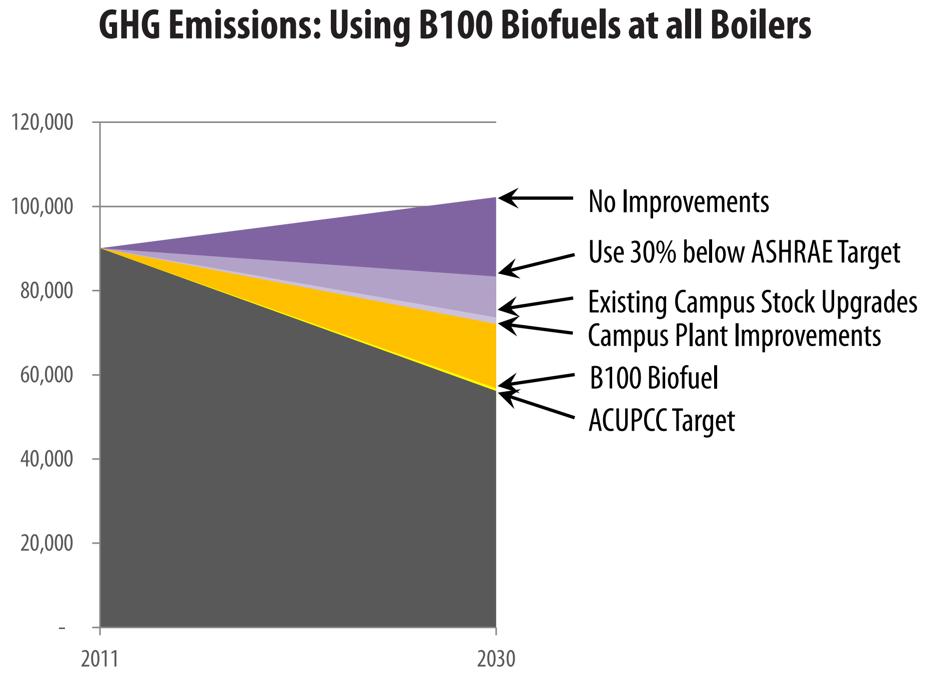
Implementing all of the measures recommended in this report still leaves an approximate 15,920 MT eCO_2 gap between the total campus GHG emissions predicted in this report, and the GHG emissions target required to be on track to reach the ACUPCC emissions reductions target. This gap can be bridged by use of renewable energy. Climate analysis found the following three renewable energy sources to be most viable: biofuels, photovoltaics, and purchased green power.

Biofuel Steam Production

Bio-based fuels, when compared to fossil-based fuels, have the advantage of being renewable, and thus from a greenhouse gas perspective bio-based fuels are GHG emissions-free or –neutral when combusted for steam generation. Bio-based fuel is available in both liquid form much like fuel oil, and also in solid form much like coal. Liquid biofuel is generally blended with petroleum fuel oil in order to lend some benefits of the renewable nature of the biofuel to the mixture but also retain the general properties of pure fuel oil. B5 (5% biofuel) is identical in physical properties to No. 2 fuel oil and can be utilized without modification to existing equipment. B20 (20% biofuel) can generally be burned in existing boiler burners with little modification and little performance degradation. Generally all that is required to switch to B20 from No. 2 fuel oil is provide a new oil gun and tips and perform a boiler retune. Use of higher grades of biofuel, (available all the way up to 100% biofuel) requires more significant alterations and modification to existing equipment and components. Depending on the grade of biofuel used, a burner and fuel oil pump replacement may even be required. It should be noted, biofuel does not provide the advantage of energy savings or improved boiler efficiency. In fact, boiler fuel consumption may increase with biofuel use due to the lower energy content of biofuel. The advantage of biofuel use lies in its inherent greenhouse gas savings. Solid bio-based fuels (often call biomass) are available in a wide variety of forms, including wood chips, sawdust, bark, corn cobs, straw grass, and many more. The use and integration of biomass fuel for combustion involves a much larger number of issues as compared to liquid biofuel. From fuel procurement and transportation, to fuel storage and fuel handling/conveying, and even ash removal and air emission permits, all are much more difficult when utilizing biomass fuel compared to liquid biofuel. These issues are common to all solid fuels are not unique to biomass fuel combustion, however for a facility not currently utilizing a solid fuel source the transition can be overwhelming and frustrating if proper consideration is not given to the key issues prior. In addition, the construction of a biomass-based steam generating facility requires a significant capital investment as well an increased annual maintenance budget.

The integration of liquid biofuel into the existing steam generating systems of both the Main and Health Science Campuses can be performed with little modification to existing equipment. All existing boilers currently utilize No. 2 fuel oil as a backup fuel to natural gas, and B20 or lower grades of biofuel could easily be substituted for the existing fuel oil supply. Existing burners should be capable of firing B20 or lower by only changing out the fuel oil gun and tips and performing a boiler tune up. If greenhouse gas savings is desired, the use of biofuel is a viable option. Steam generation utilizing biomass is also a viable, albeit complicated and intricate option as described previously. Sources of biomass fuel are located within the immediate counties surrounding the campuses but availability would have to be determined at the time of contracting. Space exists at the Main Campus steam plant for construction of a fuel storage area and a boiler room addition for a biomass boiler. A biomass fuel system capable of 20,000 PPH requires a significant capital investment with an approximate construction cost of $7 to 8 million. Such an option utilizes direct combustion of the solid fuel inside a boiler. If a gasification-type system is considered, where the biomass fuel is gasified for combustion, the approximate construction cost is greater than $17 million for a 20,000 PPH system. While biomass fuel use for steam generation does provide greenhouse savings, one must be willing to accept the required capital investment as well as ongoing maintenance costs.

If by year 2030, all steam produced on campus was generated using B100 (full biomass) fuels, the campus could reduce its GHG emissions by 15,300 MT eCO_2 - nearly enough to reach the ACUPCC goal. Full implementation of a B100 bio-fuel approach for campus steam plants wouldbe a major investment, and other means of reaching the ACUPCC target might be more cost effective.



Photovoltaics

The GHG emissions gap can also be closed by installation of several large photovoltaic arrays throughout campus. Photovoltaic panels convert the sun's energy into useable electricity. To reduce campus emissions by 15,962 MT eCO_2, photovoltaics would need to produce just over 30,000,000 kWh per year, requiring a total of 42 megawatts in PV arrays which would cover nearly 262,000 square feet, or 6 acres of campus. Obviously this approach would be prohibitively expensive. It would not be cost effective to bridge the gap using on-site photovoltaics alone, but perhaps a portion of the gap could be met using photovoltaics. Additionally. photovoltaics could be added using a power purchase agreement, effectively by leasing campus roofs to a company that installs the photovoltaics in turn for a contract to provide campus electricity at a negotiated rate.   Private companies can take advantage of any local or federal tax incentives that encourage use of renewable energy systems, making the installation more economically viable.

Purchased Green Power

In lieu of installing on-site renewable energy systems, the GHG emissions gap can also be closed by purchasing "green" power - electric energy produced by renewable sources. Typical sources used to create green power include solar, wind, geothermal, biomass, and low-impact hydropower. Green power is often more cost effective because electricity generation is not limited by the microclimate found on campus. To reach the ACUPCC goal, just over 30,000,000 kWh per year of green power would need to be purchased, equivalent to 23% of the predicted electricity consumption of the master planned campus. The table below lists the green power purchased at other Universities across the country, both in total kWh of purchased green power, as well as in percentage of overall campus electricity coming from purchased green power. In many institution the annual cost premium for purchased green power is met through student fees. For instance, in April 2000, Colorado University - Boulder became the first university to increase student fees by $1 per student to purchase green power, based on a student vote that passed by a 5 to 1 margin.

Institution	Green Power Purchased		
Oregon State	95,005,040	kWh	100%
University of Utah	93,374,904	kWh	31%
University of Colorado	20,312,764	kWh	16%
University of Washington	14,956,000	kWh	5%
Northwestern	74,311,195	kWh	30%
University of Wisconsin	69,891,198	kWh	15%
Ohio State	60,810,000	kWh	10%
University of Pennsylvania	200,194,600	kWh	48%
Carnegie Mellon	116,015,000	kWh	100%
University of Oklahoma	97,201,680	kWh	56%
Iowa State	15,800,100	kWh	8%
Drexel	84,268,000	kWh	100%
Hofstra	6,000,000	kWh	11%
George Mason	5,623,000	kWh	5%
Dickinson	18,000,000	kWh	100%
Franklin & Marshall	15,771,500	kWh	81%
Haverford	14,000,000	kWh	100%
Swarthmore	13,904,090	kWh	100%
Gettysburg	12,690,000	kWh	63%
Bentley	25,000,000	kWh	100%
Adelphi University	20,263,800	kWh	100%
Southern New Hampshire	17,500,000	kWh	100%
Saint Rose	1,235,000	kWh	12%
Georgetown	36,511,500	kWh	25%
Syracuse	22,900,000	kWh	21%
DePaul	3,800,000	kWh	7%
University of Buffalo	57,750,000	kWh	26%
Central Michigan	5,097,705	kWh	8%
Catholic University	43,000,000	kWh	100%
Goucher College	11,202,000	kWh	100%

Institution	Green Power Purchased		
American University	55,033,500	kWh	100%
Bucknell University	4,006,750	kWh	10%
Western Washington	40,000,000	kWh	100%
Quinnipiac	37,744,000	kWh	100%
Monmouth	1,947,890	kWh	10%
Santa Clara University	30,072,708	kWh	100%
Loyola Marymount University	4,615,400	kWh	16%
St. Thomas	14,302,400	kWh	43%
Augsburg	12,824,000	kWh	100%
Carleton	4,200,000	kWh	28%
Central Oklahoma	26,000,000	kWh	100%
Lewis & Clark	12,978,559	kWh	100%
Pacific Lutheran	7,764,660	kWh	45%
Whitman	5,239,753	kWh	36%
Evergreen	14,141,400	kWh	100%
Southern Oregon	11,255,640	kWh	100%
University of Denver	15,100,000	kWh	36%
Middle Tennessee	8,625,000	kWh	12%
Allegheny	14,939,000	kWh	100%
Oberlin	8,139,378	kWh	31%
Southwestern University	17,900,000	kWh	100%
Centre College	4,140,000	kWh	32%
St. Mary's College Maryland	22,004,727	kWh	100%
Colby College	7,578,077	kWh	52%
Hamilton College	6,728,681	kWh	27%
Middlebury College	2,667,929	kWh	10%
Connecticut College	2,250,000	kWh	15%
Bowdoin College	1,100,000	kWh	6%
Duquesne University	12,020,000	kWh	33%
University of Richmond	3,851,232	kWh	10%

11. CONCLUSION

By year 2030, upon fully implementing the master plan, the ECU campus will have grown in size from 6.3 million square feet to 8.9 million square feet, a 142% increase in total building size. This increase in size could increase the campus GHG emissions associated with the operation of buildings from approximately 90,000 MT eCO_2 to 102,000 MT eCO_2. By setting energy conservation targets for new construction and major renovations, implementing energy retrofits to the existing building stock, upgrading and improving campus plants and infrastructure, and purchasing green power, ECU can grow while at the same time decrease its GHG emissions by 55%, by year 2030.   If GHG emissions reductions keep at this pace, ECU would be on track to meet the ACUPCC GHG emissions reduction target of 80% by year 2050. This Energy and GHG Emissions Report identifies a path for reaching these important goals, selecting strategies that are cost-effective, achievable, and consistent with the East Carolina University Master Plan.