Energy Consumption Metrics of MIT Buildings

By

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ABSTRACT

With world energy demand on the rise and greenhouse gas levels breaking new records each year, lowering energy consumption and improving energy efficiency has become vital. MIT, in a mission to help improve the global energy system, launched the MIT Energy Initiative in 2006, and is aggressively trying to improve campus-wide energy consumption. MIT has also teamed up with the NSTAR utility company and pledged to reduce electricity generation by 15% by 2013 to serve as a model for others to follow. This thesis presents a measurement of the current performance of the most recent energy practices and seeks to provide a direction for future improvements. Following energy consumption over the course of the past decade, energy performance for the MIT campus and its buildings could be observed. It was determined that the majority of efforts to improve energy efficiency have been successful. Improvements to the campus' largest consuming laboratory buildings have significantly reduced consumption, and new energy projects have provided millions of dollars in yearly savings. Behavioral projects have not yet shown widespread success across campus but have had a drastic reduction effect in student residences where energy consumption has decreased 23% since 2006. Many buildings, which are not the largest energy consumers on campus, are continuing to increase consumption and need to radically improve for MIT to decrease overall consumption.

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1 Introduction

1.1 Motivation

Energy demand is on the rise; with an exponential population, a rapidly developing world, and a more technology flooding the market, a decline is far from in sight. With the recent awareness of drastic environmental effects such as global warming, there is a need for abrupt changes. Raising awareness and properly measuring energy consumption is the first step to properly stemming these growing energy concerns. By pinpointing problem areas around the country, on campus, or in the home, more dramatic energy decreases can be discovered and realized. These energy savings will not only provide monetary benefits, but help eliminate greenhouse gas emissions and reduce world dependence on fossil energy.

1.2 World Energy and Global Warming

In 2006, the world consumed approximately 426 quadrillion BTUs (quads) of primary energy, a 19% increase from 2000.[1] The world rate of consumption increase was nearly 2% each year for the past decade, creating a considerable amount of strain on energy markets. The United States, although responsible for 23.5% of all energy consumption (100 quads) in 2006, has had a nearly constant energy consumption rate since 2000 of less than .15% per year (as of 2008, the average dropped to .04% each year for 8 years).[2] Table 1 shows the United States compared to the rest of the world. While the U.S. maintained nearly constant consumption, China has increased consumption considerably. In 6 years, China nearly doubled its primary energy consumption, and it is forecast to surpass the U.S. consumption within the decade.[2] With population continuing to climb, and underdeveloped economics growing, energy consumption may not on track to slow.

Table 1: Primary energy consumption (quadrillion BTUs) of the United States, China, and Europe, compared to the rest of the world.

	Primary Energy Consumption: 2000 (quads)	Primary Energy Consumption: 2006 (quads)	Increase in Energy Consumption: 2000 to 2006
United States	98.98	99.86	0.89%
China	37.18	73.81	98.52%
Europe	81.53	86.42	6.00%
Rest of World	180.24	212.18	17.72%
Total	397.93	472.27	18.68%

In addition to the fears of unsustainable energy use, global warming has become a major factor in recent energy decisions. In 2007, the Intergovernmental Panel on Climate Change (IPCC) produced its fourth report, and conclusively showed significant climate effects from energy consumption. Carbon dioxide levels have been reaching new records each year, and without mitigation, serious adverse effects could ensue[3]. Figure 1 shows the CO_2 readings at the Mauna Loa Observatory in Hawaii from 1960 through 2010. These readings show that CO_2 levels in the atmosphere continue to grow each year, with a rate that now exceeds 1 part per million (ppm) per year. The IPCC has warned that these dramatic increases in CO_2 and other greenhouse gases (GHG) could cause significant temperature rises of up to 7°C with no stabilization of GHG levels.[4]

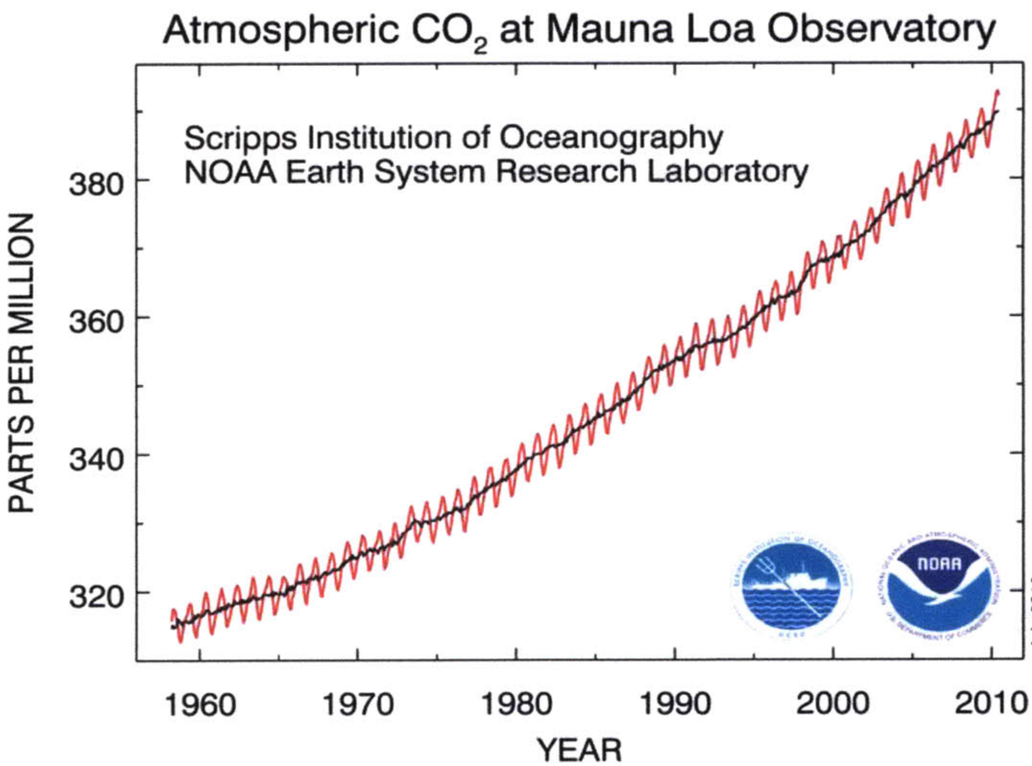


Figure 1: Readings of atmospheric CO_2 levels at the Mauna Loa Observatory in Hawaii.[5]

These findings have led to meetings of the Conference of the Parties (COP), and at the COP15, countries signed the Copenhagen Accord and pledged different amounts of GHG abatements. The United States pledged to reduce GHG emissions by 17% of 2005 levels in 2020 en route to 83% reduction by 2050[6]. Although there is difficulty in the aggressive pledges of the Copenhagen Accord, it shows the urgency of the global warming issue.

1.3 MIT Energy Initiative

MIT, in striving to be on the forefront of world issues, has made a commitment to combat the world energy problem. In response, in 2006, MIT launched the MIT Energy Initiative (MITEI) to provide answers to growing global energy concerns. The purpose of MITEI was to research, educate, and manage campus energy through innovative technologies, global systems, and outreach programs[7]. To be more aggressive on campus, MITEI launched the Walk the Talk task force in 2007 to educate the campus about energy as well as 'greening' the campus itself. Through awareness and education of students, Walk the Talk aimed at reducing energy consumption through behavioral changes and student involvement. Additionally, in 2010, MIT launched the MIT Efficiency Forward program with NSTAR to cut electricity consumption on campus by 15% in 3 years.

2 Energy Consumption at MIT

2.1 Energy Consumption of the MIT Campus

MIT buildings consume energy in 4 principal ways: electricity for general purposes, chilled water for primary cooling, steam for the majority of heating and hot water, and natural gas for limited heating and research applications. This energy is primarily supplied by the MIT Cogeneration Plant, but electricity is also supplemented by the NSTAR utility company (with supplemental electricity reaching as high as 100% of MIT capacity during the summer months). The MIT Cogeneration plant utilizes waste heat to produce steam, making it 18% more efficient than standard combined cycle systems.

The end use energy consumption by MIT buildings is depicted in Figure 2. Buildings consumed the most energy through steam, using more than 1.05 billion lbs of steam in 2009, or 1.16 trillion BTUs of steam energy. Electricity accounted for 842 billion BTUs in 2009, while chilled water and natural gas accounted for 662 billion and 91.5 billion, respectfully.

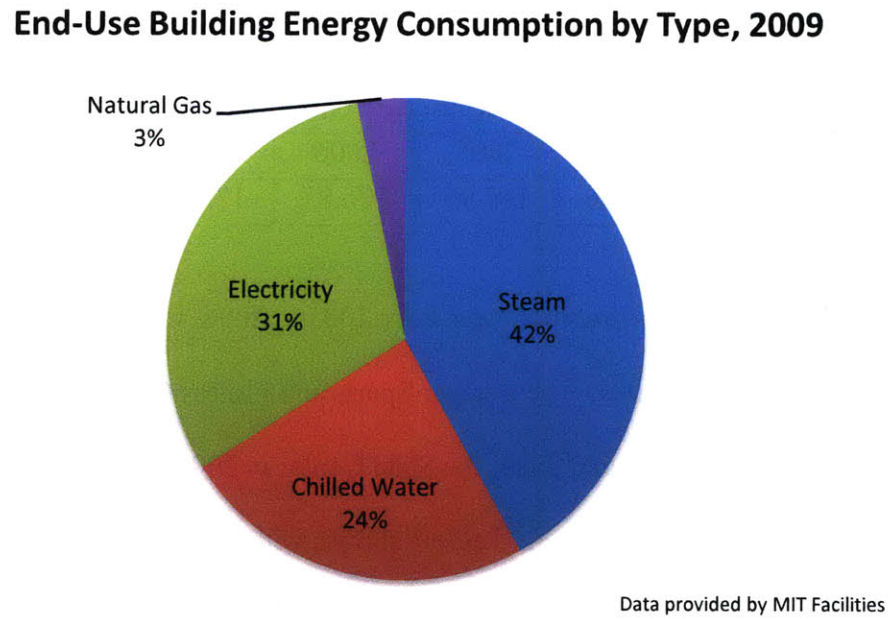


Figure 2: Percentage of MIT energy consumption by end-use type. Although natural gas is used to power the MIT Cogeneration plant, the actual buildings don't consume very much gas.

2.1.1 End-Use Electricity Consumption

MIT buildings consumed approximately 247 gigawatt hours (GWh) of electricity in 2009. The MIT Cogeneration plant provides 66% of this electricity, with NSTAR feeding the rest of the load. In addition to producing the electricity, MIT operates and services 73% of its electrical load, with NSTAR backup generation, in a majority of buildings, including all main campus buildings, a majority of east and west campus, and a handful of north campus buildings.

The data provided in Table 2 shows the yearly electricity consumption of the MIT operated buildings. These buildings used 180.3 GWh in 2009, a 22.2% increase from their consumption in 2002. However, since 2006, their electricity consumption has remained fairly constant, posting only a 1.9% increase over the 4 year span.

Table 2: Yearly electricity consumption for MIT operated buildings, 2002 through 2009.

Yearly End-Use Electricity Consumption (GWh)							
2002	2003	2004	2005	2006	2007	2008	2009
146.96	148.72	156.66	165.95	176.87	175.68	178.79	180.34

Notable increases, occurring each year from 2003 to 2006, were the result of the construction of new MIT facilities. The Zesiger Sports and Fitness Center and Simmons Hall added considerable load in 2003 and 2004, the Stata Center in 2004 and 2005, and the Brain and Cognitive Sciences building in 2006. As Table 3 shows, with the new constructions considered and removed, and using only buildings consuming electricity since 2002 and before, MIT operated buildings only increased consumption 3.23% since 2002, and have decreased .91% since 2006.

Table 3: Yearly consumption of MIT operated buildings, 2002 through 2009, using only the electrical consumption of buildings present in 2002.

Yearly End-Use Electricity Consumption (GWh, 2002 Base Year Buildings)							
2002	2003	2004	2005	2006	2007	2008	2009
146.96	145.17	148.17	151.29	153.10	147.29	152.16	151.71

2.1.2 End-Use Steam Consumption

MIT outputs steam for heating and hot water through many of the buildings on campus. 1.05 billion lbs of steam were consumed during 2009, enough steam to fill 200 Olympic-sized swimming pools full of water. This represents a 2.3% increase over 2008. Since 2002, MIT buildings have increased total consumption of end use steam 74.1%. However, as with electricity consumption, the majority of increased steam consumption stemmed from new constructions. Yet, unlike electricity, some of the increased consumption was adding new steam utility to previous buildings. As shown in Table 4, extensive increases in steam consumption occur each year from 2002 until 2005 and then remain fairly stable. From 2005 to 2009, steam consumption only increases 5.3%, or roughly 1% per year.

Table 4: Yearly consumption of steam by MIT buildings, 2002 through 2009.

Yearly End-Use Steam Consumption (Billion BTUs)							
2002	2003	2004	2005	2006	2007	2008	2009
663.5	885.2	972.1	1097.3	1098.3	1038.9	1129.6	1155.1

Table 5 shows steam consumption with only 2002 end-users throughout the same time period. With the exception of a large amount of increased consumption from 2002 to 2003, steam consumption remained at much lower increases overall.

Table 5: Yearly consumption of steam by MIT buildings, 2002 through 2009.

Yearly End-Use Steam Consumption (Billion BTUs, 2002 Base Year Buildings)							
2002	2003	2004	2005	2006	2007	2008	2009
663.5	864.6	929.5	980.2	907.4	841.1	903.5	906.7

The large increase seems to stem from 2002 having been an anomaly year with respect to steam consumption on MIT campus. Nearly every building on campus saw a drop in consumption from 2001 to 2002, with almost every building drastically increasing consumption in 2003. 2001 end-user steam consumption was 728 billion BTUs which does account for some of the upswing, albeit not all of it. Because 2003 onward were so consistent, those values are better for analysis.

2.1.3 End-Use Chilled Water Consumption

Chilled water is used as MIT's primary source for cooling, and accounts for 24.1% of the total energy consumption on campus. The 675 billion BTUs of energy consumed in 2009 was equivalent to 56,260 tons of chilled water, or 7 million gallons. Although the consumption of chilled water was not as high in 2009 as in 2006 (for either 2002 base buildings or all buildings), end-use chilled water consumption was still up 36.4% and 18.4%, with respect to 2003. As shown in Tables 6 and 7, chilled water usage across campus is off its 2006 high, but MIT campus made some large consumption increases. However, chilled water accounted for 24.7% of total consumption in 2003, and still remained at approximately the same ratio in 2009.

Table 6: Chilled water consumption from 2002 to 2009 in billion BTUs.

Yearly End-Use Chilled Water Usage (Billion BTUs)							
2002	2003	2004	2005	2006	2007	2008	2009
385.596	495.143	552.108	568.263	710.193	666.876	643.608	675.142

Table 7: Chilled water consumption from 2002 to 2009 in billion BTUs using only buildings consuming chilled water in 2002. This shows that the increases were not solely caused by newly serviced buildings.

Yearly End –Use Chilled Water Usage (2002 BY, Billion BTUs)							
2002	2003	2004	2005	2006	2007	2008	2009
385.596	468.628	515.247	510.335	615.26	536.441	520.033	554.569

2.1.4 End-Use Natural Gas Consumption

Natural gas, which is MIT's largest primary energy source, is only 3.3% of the end-use consumption of MIT (MIT Cogeneration Plant uses natural gas fuel to create the electricity, steam, and water at a chilled temperature). As Table 8 shows, end-use gas consumption has also been very consistent over the past decade. An increase in consumption in 2003 was caused by research in the building 44 Cyclotron, but otherwise, fairly steady consumption across campus. Because few buildings use a considerable amount of natural gas, the change in natural gas between 2002 base buildings and 2009 buildings is negligible.

Table 8: Natural gas end-use consumption 2002 to 2009 in billions of BTUs.

Yearly Natural Gas End-Use Consumption 2002 to 2009 (Billion BTUs)							
2002	2003	2004	2005	2006	2007	2008	2009
95.0319	115.2154	93.0971	94.0182	100.7908	93.7611	94.8337	93.7577

2.2 Summary of MIT Building Consumption

Laboratories typically consume the most energy of all the MIT buildings, consuming almost twice the energy of the average MIT building[8]. Of the largest consuming buildings on MIT campus, 8 of them have 25% or more of the total building square footage designated to laboratory space, as defined by MIT Facilities[9]. Table 9 shows the 10 largest consumers on MIT campus by consumption volume. Only the Stata Center and the Z-Center do not have 25% or more of the building area designated to laboratories (8% and 0% respectfully).

Table 9: Largest energy consuming buildings by volume on MIT Campus, % of whole.

Ten Most Energy Consuming Buildings on MIT Campus		
1.	Building 46	7.91%
2.	Building 68	5.08%
3.	Building 39	4.17%
4.	Building 56	3.41%
5.	Stata Center	3.33%
6.	Building 13	3.19%
7.	Building 18	2.59%
8.	Building 16	2.36%
9.	Z - Center	2.12%
10.	Building E18	2.09%

Along with laboratory buildings consuming the most energy, they also have the highest energy per unit area. Table 10 shows the 10 highest consuming buildings per square foot (sq. ft.), and upon that list, 9 out of the 10 buildings are 25% or more laboratory space. Lab space has a higher need for energy due to the energy intensive nature of the research being conducted; typically fume hoods, clean rooms, animal quarters, and large machines consume an enormous amount of energy to operate and maintain. Energy intensive practices are not needed in offices, residences, or public areas, and thus many buildings naturally do not require as much energy.

Yet, due to the large quantities of energy being used in lab buildings, much of the focus of energy conservation has been on the buildings listed in Table 9 and Table 10. Table 11 shows the 6 biggest decreases in energy consumption since 2005. On that table, 5 of the 6 buildings are laboratory buildings from the previous two tables.

Table 10: Ten most consuming buildings on MIT campus in kBTUs per sq. ft.

Largest Energy Consuming Buildings (kBTUs per sq. ft.)		
1.	Building 39	1678.6
2.	Building E34	1280.3
3.	Building W91	822.0
4.	Building 56	732.9
5.	Building 16	617.2
6.	Building E17	612.8
7.	Building 18	608.3
8.	Building 68	589.9
9.	Building 46	585.3
10.	Building E18	554.9

Table 11: Largest decrease as a % of 2005 consumption, 2005 to 2009 (minimum of 20 billion BTUs consumed in 2009).

Largest Decreases In Energy Consumption 2005 to 2009		
1.	Simmons Hall	-39.1%
2.	Building 18	-34.2%
3.	Building 16	-27.1%
4.	Building 13	-26.3%
5.	Building 68	-23.5%
6.	Building 39	-14.2%

The focus on laboratory buildings has created a considerable drop in total energy consumption among the largest building consumers. Since 2005, the ten largest consuming buildings, with the exception of building 46 which had not been built yet, have decreased total energy consumption by 17.4%. This accounted for 160 billion BTUs of energy, or 6% of MIT total energy consumption in 2009.

However, total energy consumption did not decreased by 6%, and in fact, continued to remain steady or slighting increase since 2005. This is explained by the increase in consumption of many more 'middle consuming' buildings, or buildings that have a sizable effect on MIT consumption, but are not top ten consuming laboratory buildings. Table 12 shows the 6 largest increases by percentage of 2005 total energy consumption. In this table are the two largest Magnet Labs, D-Lab, the IST Data Center, the physics building, and the humanities complex. Additionally, the main ground of buildings, buildings 1-8, 10, and 11, collectively have increased 12.4% since 2005, representing 45 billion BTUs of increase.

Table 12: Largest increases in energy consumption as a % of 2005 total, 2005-2009 (minimum of 20 billion BTUs consumed in 2009).

Largest Increases In Energy Consumption 2005 to 2009		
1.	Building E34	358.5%
2.	Building NW13	157.5%
3.	Building W91	148.4%
4.	Building NW14	144.6%
5.	Building 6	58.9%
6.	Building 14	43.3%

3 Analysis of MIT Energy Programs

3.1 Facilities Energy Projects

With a lot of attention being brought to possible energy savings in MIT buildings, MIT, through its facilities department, has been renovating current buildings with a number of energy projects. Such projects include recalibration of fume hoods, controls on ventilation fans, replacement of steam traps, automated lighting controls, and new lighting fixtures.

In the past four years, $2.4 million dollars have been spent renovating and repairing current buildings to improve efficiency and decrease energy consumption. Estimates for the energy savings of recent projects are approximately $2.5 million. 30 projects were recently undertaken, and more energy projects are in the works. Table 13 shows 4 of the earlier projects, with savings estimates by MIT Facilities, and calculated savings costs from recent energy data.

Table 13: 4 projects completed by MIT facilities.

Building	Project Type	Completion Date	Estimated Savings ($2009)	Savings Since Completion ($2009)	Approximate Energy Savings (Billion BTUs)
Z Center	HVAC	2008	$231,000	$320,000	18.8
Building 18	HVAC	2008	$249,000	$284,000	11.3
Building 68	HVAC	2009	$221,000	$179,000	14.0
W20	Lighting	2009	$33,000	$32,000	0.7

Although there is a significant upfront cost to many of these energy projects, most will return the benefits quickly. These projects typically produce immediate decreases in energy consumption. And although the benefits are useful in the short term, their long term conservation keeps costs down. For example, a graph of the monthly steam consumption at the Zesiger Sports and Fitness Center, depicted in Figure 4, shows a noticeable decrease in month over month consumption of steam since the early 2008 completion of the HVAC energy project. In 2008, the Z Center saw savings of 2.9 million lbs of steam over 2007, and then another 3.4 million pounds in 2009 over 2008 consumption.

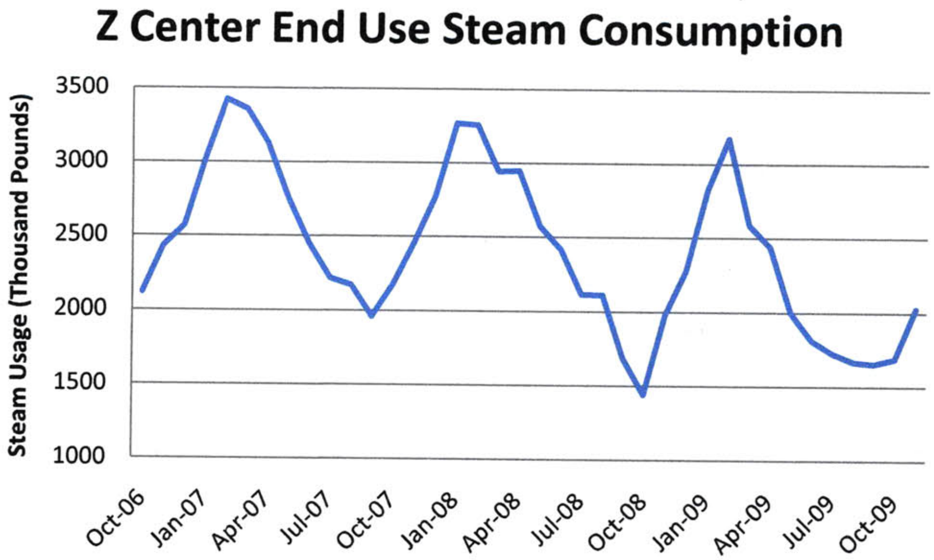


Figure 3: Zesiger Center Steam Consumption from October 2006 to January 2010. The graph shows and noticeable decline in steam consumption, partially corresponding to the energy project completed in early 2008.

3.2 Behavioral Energy Projects

There are a number of energy projects around campus that are focused on behavioral changes. MIT launched the "Walk the Talk" program in 2007, with one of the major goals to be energy education. By educating students, faculty, and the community, MIT hoped people would change personal energy habits and consume less, thereby saving energy and keeping greenhouse gases out of the atmosphere. Such energy education, including a number of new classes on the MIT campus, pre-orientation programs, student-run organizations, and public energy displays focus on informing the campus community about many different aspects of energy. Other behavioral programs, such as the MIT Sustainability Pledge Effort and the Dorm Electricity Competition, are geared directly at involving students in bringing down consumption. The education, along with the programs, has had an immediate effect on student residences. Student residences have decreased electricity consumption 6.5% from 2006 to 2009, and total energy consumption has decreased 22.8% during the same time period, as can be seen in Table 14.

Table 14: Percentage change in dormitory electricity and total energy consumption with respect to 2006 usage. Random Hall and NW35 are not included because of insufficient data for those residences.

Dormitory Consumption Change 2006 to 2009

Dormitory	Electricity	Total Energy
Baker House	-15.5%	-12.4%
Bexley Hall	-27.9%	-35.7%
Burton Conner	1.3%	-29.2%
Senior House	-21.0%	-20.2%
East Campus	-13.6%	-24.0%
McCormick Hall	27.3%	-3.8%
McGregor House	-3.5%	-26.7%
New House	-13.0%	14.3%
Next House	17.2%	-27.6%
Simmons Hall	-6.3%	-41.1%
Green Hall	-14.3%	-33.7%

The data shows a significant effect in residences, but residence halls only accounted for 4.5% of energy in 2009. To contrast, the main group buildings, buildings 1-8, 10, and 11, increased energy consumption by 9.5% during the same period (2006 through 2009), and used 13.5% of MIT load in 2009. Although large lab buildings and residence halls are taking advantage of energy decreases, MIT's energy is remaining constant, pointing to significant increases across the rest of campus.

4 Conclusion

4.1 Results

MIT's projects directed at particular buildings have greatly reduced energy consumption in highly consuming lab buildings, new buildings, and residence halls, but are failing to reduce total campus consumption. Energy consumption over the entire MIT campus has remained nearly constant for time period 2006 through 2009. Large lab buildings, such as buildings 39 and 18, which have been previously written about and/or focused upon, have had substantial decreases in energy consumption. The 10 largest buildings decreased 17.4% over the last 4 hours, and more energy projects for these buildings are currently being completed. As well, student residence halls have had significant improvements in energy consumption because of better energy education, energy signs and posters, and energy competitions. MIT dormitories have dropped 22.8% of total energy consumption over the past 3 years and continue to have projects undertaken. Many of MIT's behavioral projects, such as posters for revolving doors and shutting lights in buildings, are not yet showing effects in the majority of MIT campus, where much of the load is more research, or educationally driven. There is a fair amount of buildings consuming more and more energy each year, but without one of the top consumptions, those buildings remain under the radar.

4.2 Going Forward and Future Research

Future research into this topic would involve, first, better metering. With better metering, as well as all knowledge of energy usage of each building, the topic could be pursued even further than this thesis would entail. The most difficult thing is detecting where all the usage is actually going; are offices using as much as laboratories, or is there a vast difference? Although estimates can be made from the facilities space inventories, they are but rough estimates since few laboratories or offices are the same. A potential project would be to implement metering in two or three buildings for two years to gain knowledge of their relative usages.

Finding a solution to the energy consumption of the older MIT buildings, for example the main group buildings, should be one of MIT's concerns going forward. There are quite a few labs that are also in those buildings, and because they are not as large as the new building labs, and don't consume quite as much energy, they seem to get less noticed.

The MIT behavioral projects are working in areas of campus that can be more affected by actual consumption changes, but buildings with labs do not seem to be catching on as quickly. This seems to be causing the disparity between the residences and the actual buildings at MIT. Further research would need to involve calculating how much energy is 'necessary' research energy to determine exactly what MIT can afford to decrease before research may be sacrificed.

APPENDIX A: CONSTANTS AND CONVERSIONS

BTU Conversion Factors	
1 kWh	3413 BTUs
1 scf Natural Gas	1040 BTUs
1 lb Steam	1100 BTUs
1 Ton-Hr Chilled Water	12000 BTUs

Cost Conversions	
1 kWh	\$0.16
1 scf Nat Gas	\$0.05
1 Ton-Hr Chilled Water	\$0.26
1000 lbs Steam	\$17

Conversions	
1 quad	10^{12} BTUs
1 CCF	100 scf
1 GWh	10^{6} kWh

Note: All years mentioned are fiscal years, with the exception of the Z-Center graph on page 23.

APPENDIX B: Energy Consumption Tables

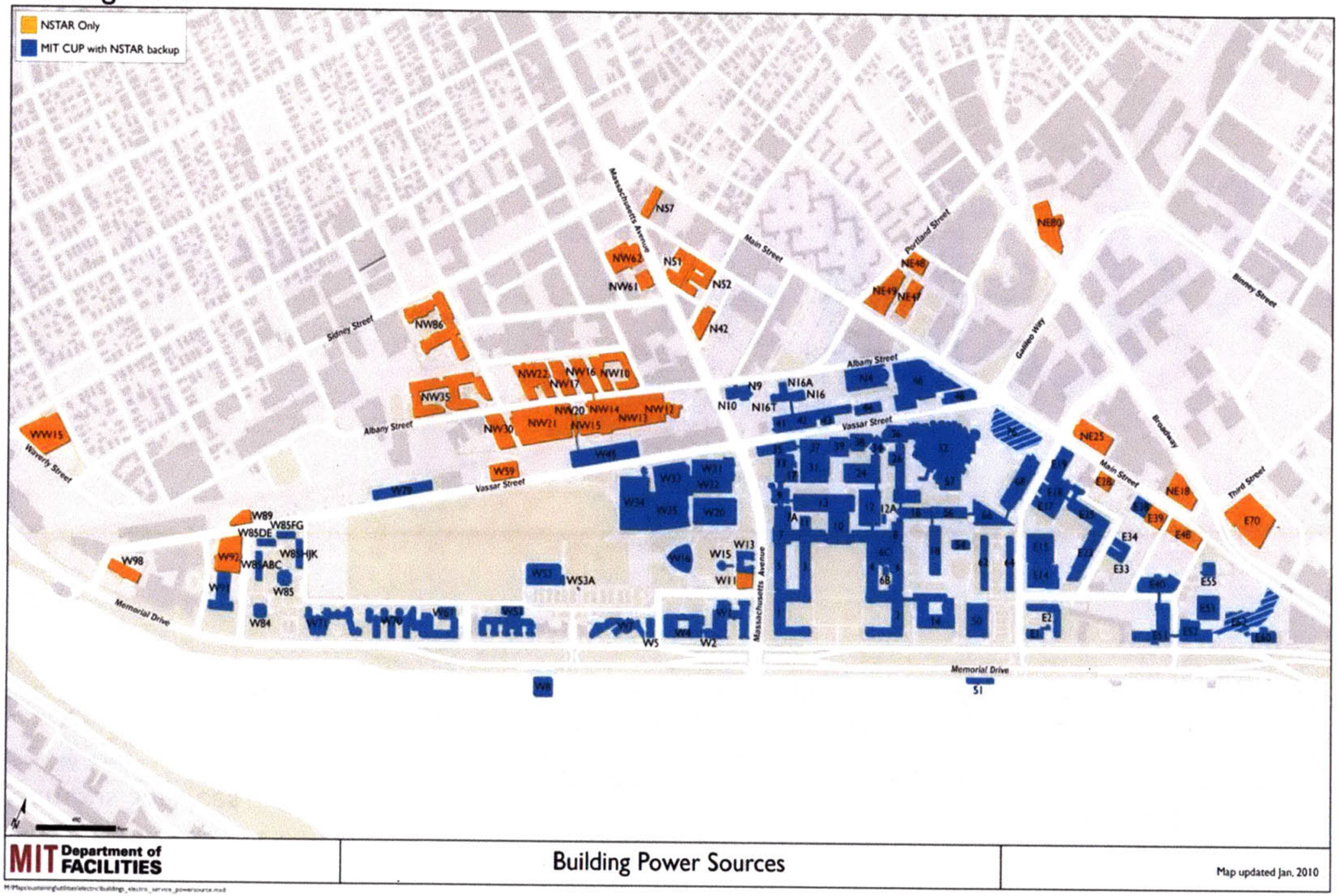
Minimum 20 Billion BTUs in Fiscal Year 2009

	Total Energy (kBTUs/sqft)				Total Energy (kBTUs/sqft)		
Building	2005	2009	Difference	Building	2005	2009	Difference
E34	279.23	1280.28	358.5%	E23	340.36	371.69	9.2%
NW13	163.75	421.63	157.5%	31	332.00	361.26	8.8%
W91	330.92	822.00	148.4%	E25	285.36	309.18	8.3%
NW14	166.79	407.99	144.6%	E18	524.37	554.87	5.8%
6	279.51	444.27	58.9%	54	250.55	261.94	4.5%
46	375.85	585.34	55.7%	W20	243.08	251.53	3.5%
14	168.65	241.59	43.3%	1	268.06	273.53	2.0%
10	216.31	303.55	40.3%	E19	236.74	238.75	0.8%
5	234.83	316.13	34.6%	E52	177.88	176.74	-0.6%
3	252.96	325.21	28.6%	32	226.38	224.37	-0.9%
36	264.02	337.08	27.7%	W34	197.69	193.64	-2.0%
2	261.73	328.35	25.5%	W35	541.32	518.56	-4.2%
E15	260.50	324.47	24.6%	E17	643.29	612.82	-4.7%
7	219.03	265.39	21.2%	56	806.19	732.91	-9.1%
66	321.27	387.39	20.6%	39	1955.98	1678.59	-14.2%
37	349.09	417.62	19.6%	68	771.07	589.92	-23.5%
26	192.87	227.58	18.0%	13	689.34	507.76	-26.3%
4	263.08	300.14	14.1%	16	846.19	617.17	-27.1%
38	291.99	326.21	11.7%	18	924.59	608.32	-34.2%
48	429.31	474.35	10.5%	W79	201.04	122.51	-39.1%

Building	Total Energy	Building	Total Energy	Building	Total Energy
46	217.59	31	21.22	W33	7.00
68	139.56	W34	19.92	E38	6.73
39	114.64	W79	19.90	W31	6.28
56	93.77	8	18.96	34	6.22
32	91.66	E53	18.05	NW15*	5.82
13	87.73	Eastgate Residence	16.93	E60*	5.20
18	71.08	9	16.71	W8	4.33
16	64.88	33	15.93	32 Garage	4.10
W35	58.39	12	15.69	Bexley Hall	3.69
E18	57.38	New House	15.25	E1	3.64
NW14*	54.46	NW35*	15.03	167 Albany Street*	3.38
6	54.30	Tang Hall	14.95	NW62*	3.38
E17	47.69	Sidney & Pacific*	14.88	44	2.97
3	47.20	Westgate Residence	14.75	WW15*	2.78
66	46.49	E40	14.51	Random Hall*	2.75
4	44.07	24	14.21	185 Albany Street*	2.60
36	43.75	Baker House	13.99	NW17*	1.99
W20	43.21	Lns Linac*	13.94	Indoor Tennis	1.98
E25	42.11	McCormick Hall	13.66	W59*	1.88
10	39.08	McGregor House	13.64	17	1.88
37	36.96	184-190 Albany St*	13.43	W11*	1.54
E15	36.13	50	12.98	N57*	1.53
2	35.78	Burton-Conner	12.36	N10	1.48
14	33.88	East Campus	11.85	Green Hall	1.40
E23	32.93	35	11.60	W45	1.38
E19	32.93	41	11.24	209 Mass Ave*	1.16
E34	31.15	N51*	11.10	Walker Dining	1.11
54	29.11	W32	11.07	W15	1.08
1	28.24	NW12*	10.29	W98*	1.05
26	27.97	E51	9.54	NE108*	1.03
7	27.74	Next House	9.50	E33	0.85
W91	26.75	W16	9.35	W92*	0.85
38	24.75	11	9.23	W89*	0.84
E52	23.75	Edgerton House*	8.94	N9	0.75
NW13*	23.67	57	8.29	Sailing Pavilion	0.48
48	23.38	Senior House	8.27	N4	0.07
5	22.73	NW30*	8.12	N52*	0.05

*All buildings marked with a * do not have any electrical data (NSTAR protected data)

Building Services



Campus Services

DRAFT

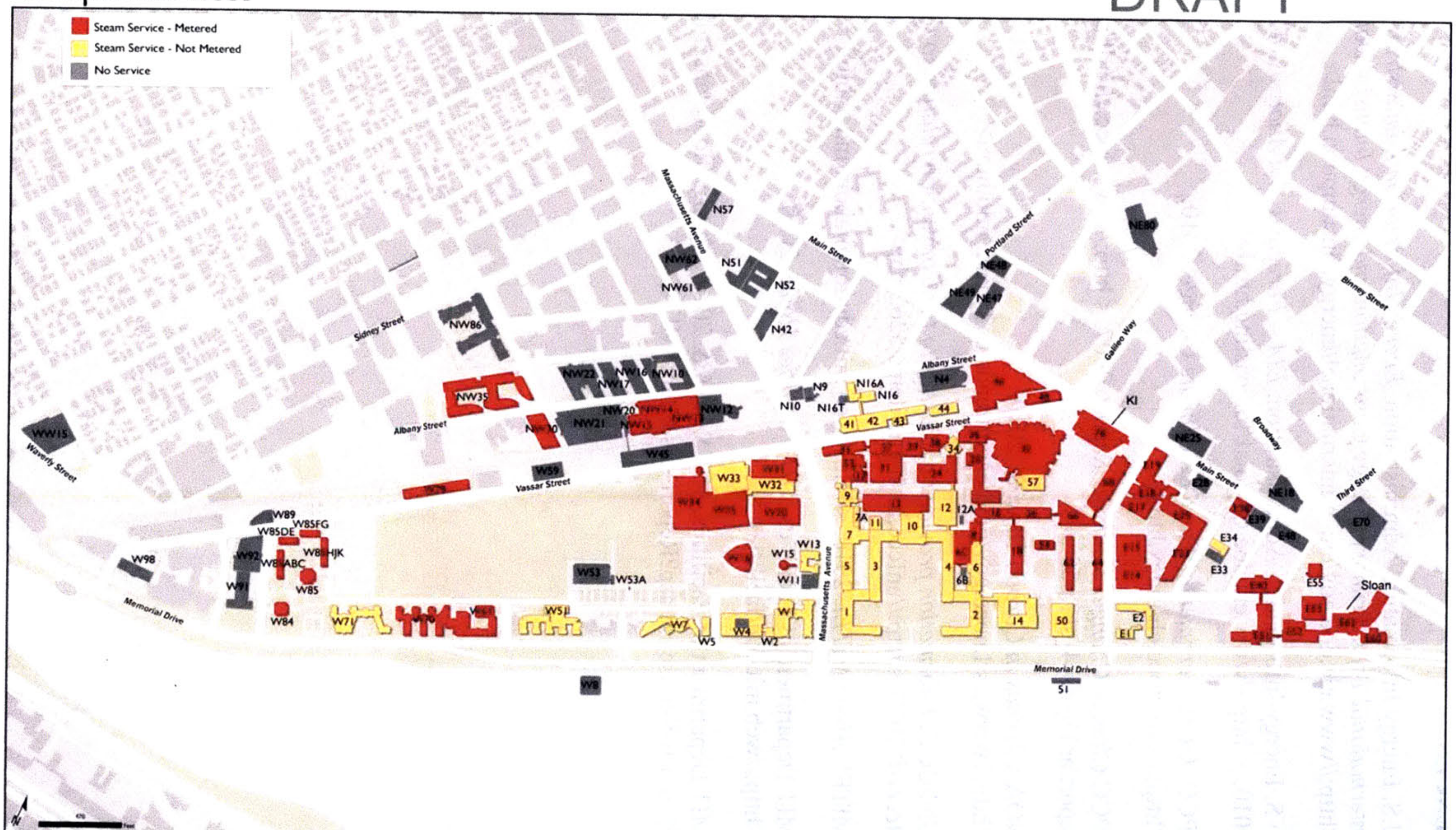
MIT Department of FACILITIES

Buildings Served by MIT Chilled Water Service

Map updated Jan, 2010

Campus Services

DRAFT



MIT Department of FACILITIES | Buildings Served by MIT Steam Service | Map updated Jan. 2010

REFERENCES

1. U.S. Energy Information Administration. *Energy Information Administration – International Total Primary Energy Consumption and energy Intensity Data*. 2010. <http://www.eia.doe.gov/emeu/international/energyconsumption.html>

2. U.S. Energy Information Administration. *EIA – Forecasts and Analysis of Energy Data.* 2010. < http://www.eia.doe.gov/oiaf/forecasting.html>

3. IPCC. *Intergovernmental Panel on Climate Change.* 2010. <http://www.ipcc.ch/index.htm>

4. IPCC *Climate Change: Synthesis Report.* 2007. < http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf>

5. NOAA *Trends in Carbon Dioxide.* 2010. <http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html>

6. UNFCCC. *Information provided by Parties to the Convention relating to the Copenhagen Accord.* 2010. <http://unfccc.int/home/items/5262.php>

7. MITEI. *About MITEI.* 2010. < http://web.mit.edu/mitei/about/index.html>

8. MIT Department of Facilities. *MIT Facilities Home.* 2010. <http://web.mit.edu/facilities/>

9. MIT Department of Facilities. *MIT SA WIBS.* 2010. <https://floorplans.mit.edu/cgi-bin-db-mit/wdbmitscript.asp?Report=ibs&Item=MIT>