LEED® Platinum
Energy Performance Case Study

Harvard University

Blackstone South

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Jeffrey Smith, Harvard University, Director of Facilities Maintenance Operations

How well does a LEED® Platinum building ***really*** perform?

Blackstone Outperforms the Energy Model

Currently outperforming the Energy Model by **16%**

(For the period: July 2009 thru June 2010)

First two years (2007 and 2008) underperformed the Energy Model by **30%**

Energy Modeling

- **What is it?**
  - simulation of anticipated energy cost for one year using the specified building materials and systems
  - provides engineers, architects, building managers with common frame of reference for use
- **LEED® NC requirements**
  - minimum 10% improvement over a baseline building that just meets the Energy Code (ASHRAE 90.1-2007)
- **Blackstone South** (2006)
  - anticipated ~40% improvement from Code

Blackstone Mechanical Systems

- **Heating:** Hot Water from Steam
- **Cooling:** Geothermal Wells and Heat Pumps
- **Ventilation:** Separated from Heating/Cooling
- **Energy Recovery Wheel**
- **Building Automation Control** System
- **Dedicated Distribution System** for Operations Center (24/7/365)

Blackstone Early Experiences

- No prior experience with Geothermal Wells or Energy Recovery Wheels
- Immediate challenges with Salty Water, Bleed Water Management, and Cooling Capacity. All had significant impacts on Operating Costs!
- Electric Sub-meters not installed for 2 years… made pinpointing early problems difficult
- Suspected Problems with the Energy Model right from the start

Design vs. First Year Actual Use

Blackstone South Energy[1] Consumption (kWh)				
Systems	Designed Use (per corrected Energy Model)	Actual Use 2007 [2]	Difference	
Operations Center	74,460			
Plug Loads	157,221			
Lighting Loads	143,420			
Mechanical Equip	95,759			
Total Building	**470,860**	**612,195**	**141,335**	**30%**

[1] All building loads converted to kWh, includes electric and steam use.

[2] Sub-meters required to determine actual energy use by system were not installed as part of the Blackstone Office Renovation Project. Sub-meters were added in May 2008, making this information available for subsequent measurement.

Energy Audit Findings
May 2008

- Plug Loads
- Lighting Systems
- Operations Center
- Mechanical Systems

Plug Loads (entire building)

- Portable meter (Kill A Watt™) used to measure actual wattage at specific devices
- Collected data on:
  - Computers and Office Equipment
  - Coffee Makers
  - Refrigerators
  - Soda Machine
- Each piece of equipment trended over 24 hours

Portable Kill A Watt Meter™

Plug Loads (entire building)

Findings

- Weekend audit found 41 computers and monitors *logged out… but still on*
  - Each computer used 77 watts *(even when logged out)*
  - Each monitor uses 44 watts *(even in screen saver)*
  - Shutting down during non-business hours would save **18,300 kWh/year**
- Removing a soda machine, two excess refrigerators, two coffee machines (and installing timers on three remaining units) could reduce consumption by **6,200 kWh/year**

Lighting Loads (entire building)

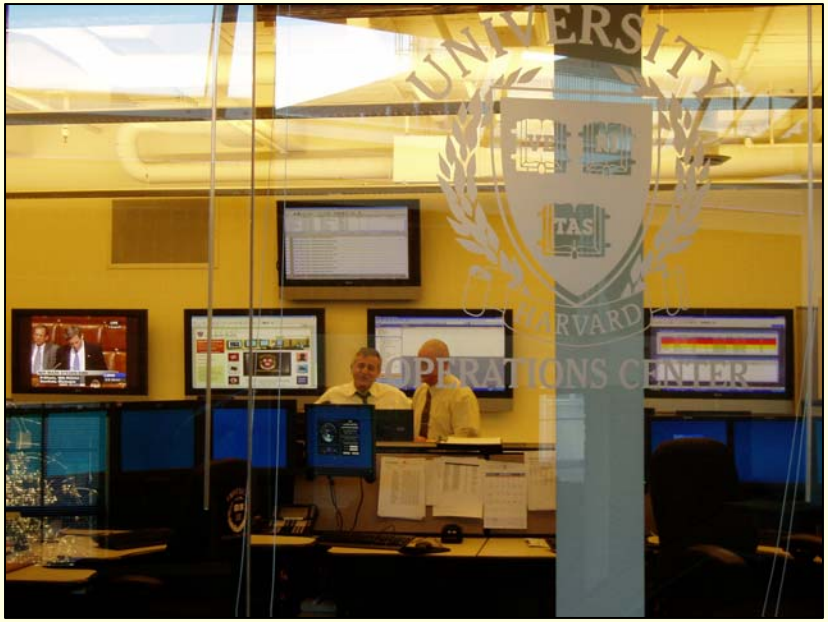
Findings

- Confirmed all occupancy sensors operating properly
- Disconnected unnecessary Track Lights: save **600 watts/hour**
- Reset timers on Exterior Lights, cut use by 4 hours a day. Savings for summer season (May through September) is **5,000 kWh**

Operations Center (24/7/365)

Includes:

- 27 personnel computers
- 51 monitors (17” each)
- 5 wall-mounted, flat panel monitors (40” each).



Findings

- Each wall panel monitor consumes **400 watts/hour**
- Turning off 4 wall monitors reduces consumption by **11,863 kWh/year**
- For every workstation (computer and monitor) shut off, consumption is reduced by 121 watts/hour or up to **1,060 kWh/year**

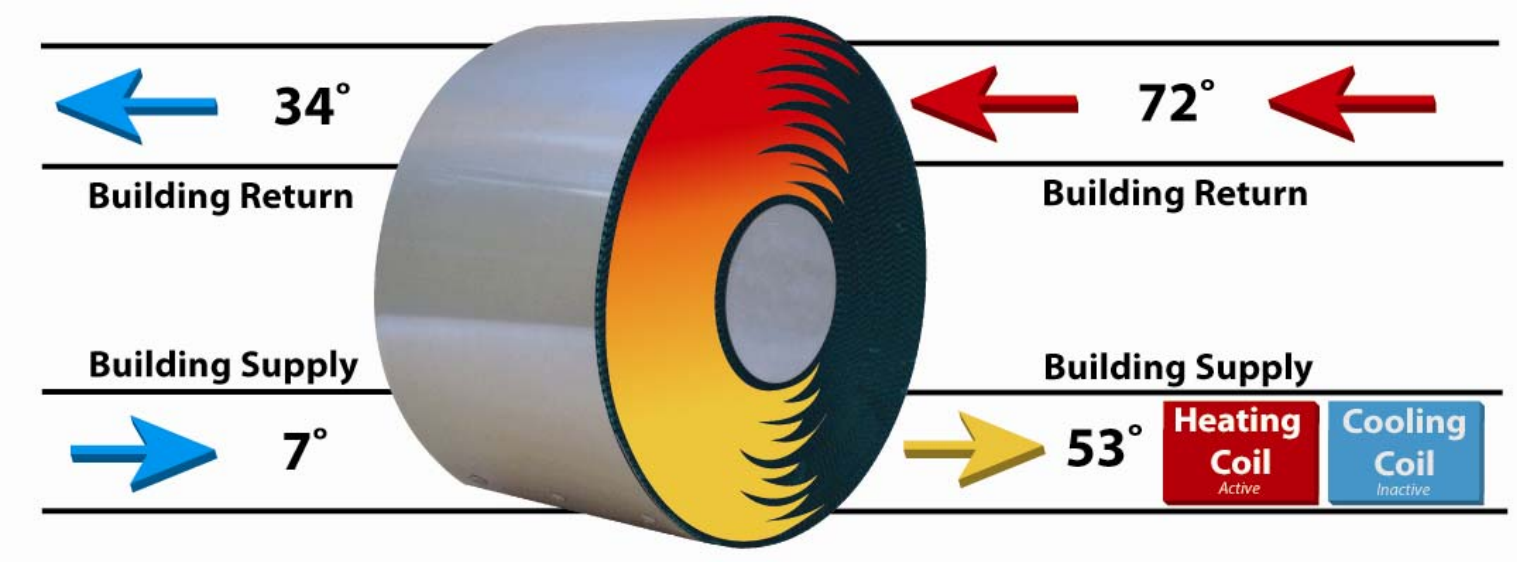
Mechanical Equipment - AHU

- Designed operate 24/7 - with integrated Energy Recovery Wheel
- Experimented by operating AHU only between 6 a.m. and 6 p.m., weekdays
- Ops Center comfort levels satisfactory (equipped with a dedicated Leibert® unit)
- Measured CO^2 levels confirmed acceptable levels (less than 600 ppm above background levels)

Energy Recovery Wheel

Findings

- Malfunctioning equipment -- losing opportunity to save **50,000 kWh annually**
- Repaired under warranty following audit



Mechanical Equipment - continued
AHU and Well Pumps

Findings

- **Air Handling Unit**
  - Night set back schedule year round saves **42,822 kWh/year**
- **Well Pumps**
  - Only one pump needed to meet winter cooling loads. (Previously, both pumps ran at 100% due to difficulties in balancing the supply and return flows.)
  - Well Pumps reprogrammed to operate only one well pump during the off-season (October – March).
  - Seasonal change will result in an energy savings of **15,000 kWh/year**

Actions and Results

- **Changes Made in 2008**
- **Energy Model Review**
- **Adjusted Model versus Actual**
- **Changes Made in 2009**

Changes Made in May 2008

System	Action	Expected Savings [1] kWh	$$$ [2]
Ops Center	Turned off 4 Flat Panel Monitors.	11,863	$1,957
Plug Loads	Instructed occupants to turn off computers before leaving. Removed excess refrigerators, soda and coffee machines	23,361	$3,020
Plug Loads	Installed shutoff timers (6 p.m.- 6 a.m. and weekends) on Coffee Makers (exception of 2nd floor for 24/7 staff)	1,141	$188
Lighting	Reprogrammed Exterior Lights to activate at 8 p.m. for summer	5,000	$800
Mechanical	Repaired Energy Recovery Wheel	50,000	$8,000
Mechanical	Reprogrammed BMS to shutdown AHU (6 p.m. - 6 a.m. and weekends)	42,822	$7,0635
Mechanical	Reprogrammed BMS to operate only one Well Water Pump during off-peak seasons (6 months).	15,081	$1,993
Totals		**149,268**	**$24,379**

[1] Annualized savings: assumes identified actions remain in place for 12 months, unless otherwise noted.

[2] Based on electricity cost of $0.165 per kWh.

Energy Model Review

- Blackstone Energy Model developed by Design Engineer used the Trane Trace 700 Data model

Most Significant Error Identified:

- Model undervalued Operations Center by **62,000 kWh annually**

Original vs. Corrected Model

Blackstone South Energy Consumption (kWh)		
Systems	**Original Energy Model** (per Design Energy Model)	**Corrected Model** [1]
Operations Center	Included in plug load	74,460
Plug Loads	169,160	157,221
Lighting Loads	143,420	143,420
Mechanical Equip	95,759	95,759
Total Building	**408,339**	**470,720**

Changes Made in 2009

- Added **Supplemental Rooftop Cooling Unit** for Ops. Ctr.
  - Free Cooling 5 months a year
  - Lowers peak for geothermal system and eliminates “Bleed Water” during Summer Season

- Installed plate and frame **Heat Exchanger** to isolate brackish water: eliminate corrosion in heat pump equipment – slight reduction in overall efficiency offset by large savings in maintenance expenses

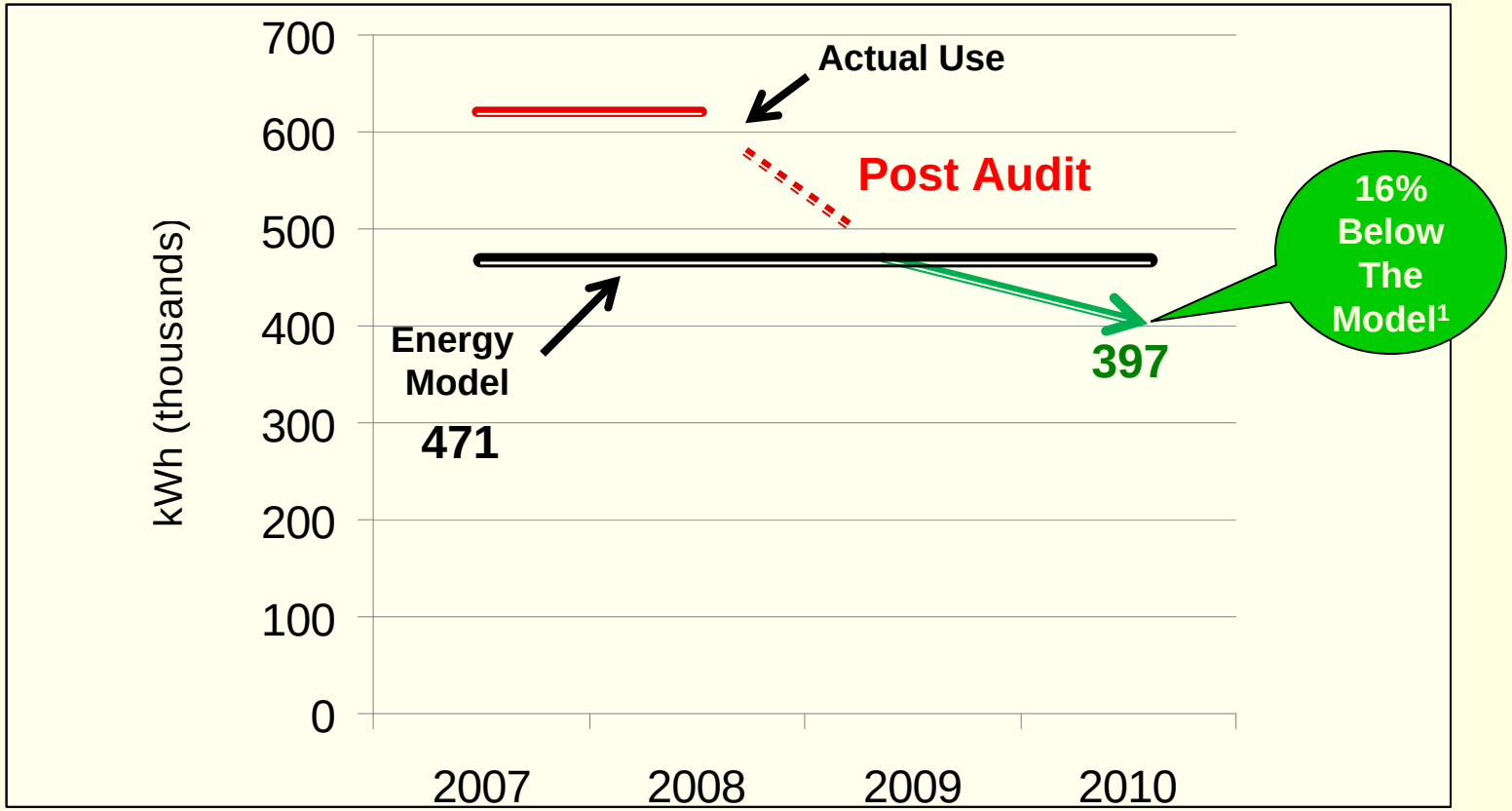
Changes Made in 2009

- Added **Solar Thermal** System for Heating Domestic Water

- Established New **Building Optimization Protocols**
  - Occupant Control of Solar Gain
  - Equipment Operating Strategies (cycling / sequencing)
  - Revised space temperature set points and staff expectations

Blackstone South

Energy Use 2007 thru 2010



[1] Most of the savings below the Energy Model result from the addition of the Free Cooling system for the Operations Center.

Lessons Learned

- **Energy Model requires careful scrutiny**
  - Operations Center was significant error in the model
- **Absence of Free Cooling was weakness of design**
  - 24 hour operation of AHU was unnecessary
- **Measurement and Verification is critical**
  - Don’t “Value Engineer” sub-meters from project scope!
- **Improvement comes from systematic review**
  - Benefit from experience of others; share your results

For more information, contact

Jeffrey Smith or Tony Ragucci

Harvard University at

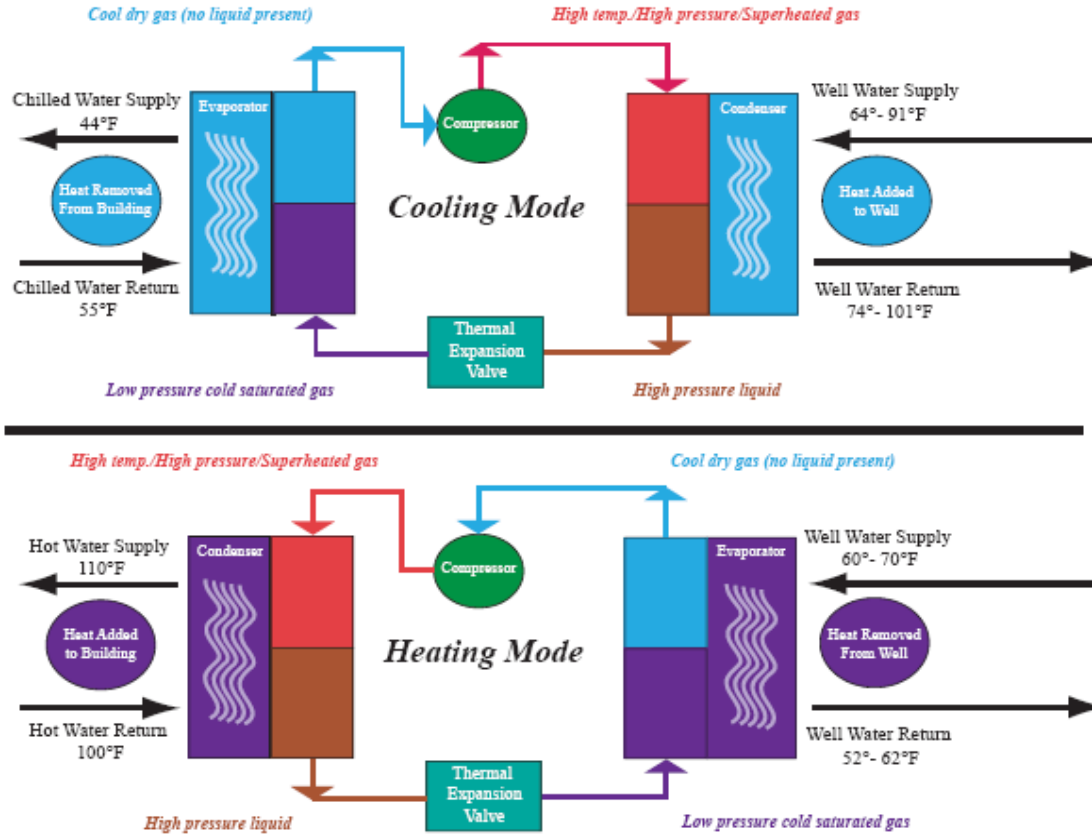
jeffrey_smith@harvard.edu

tony_ragucci@harvard.edu

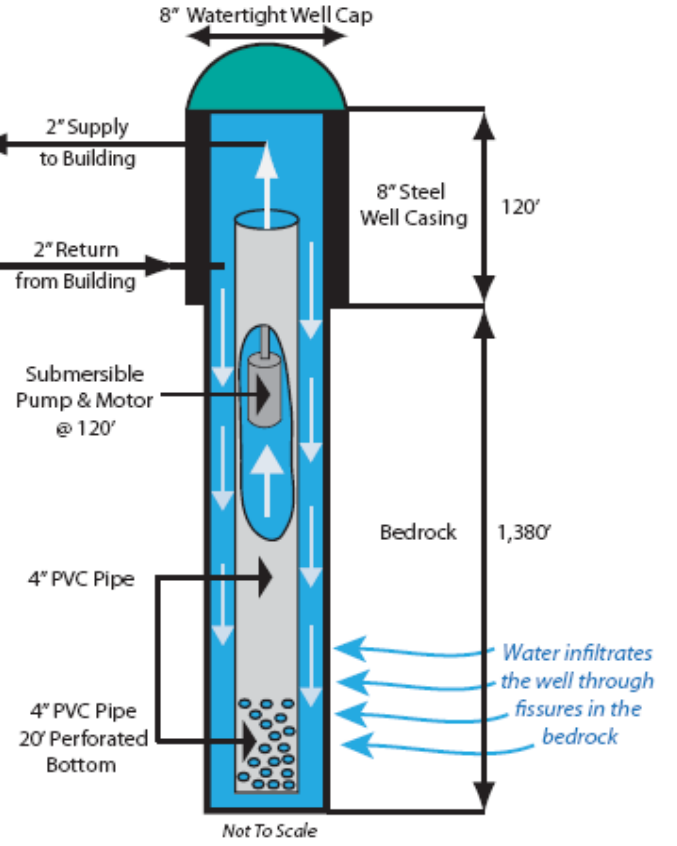
Appendix

- Diagram of Blackstone Geothermal Well Installation
- Operations Center – Energy Model Impact
- Email sent to Building Occupants: Computer Shutdowns
- Daily Plug Load Trends following Occupant Education
- Power and Heat Load Savings from Computer Shut Down

Heat Pump Refrigeration Cycle



Blackstone Well Installation



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Facilities Maintenance Operations

Original Energy Model Undervalued Operations Center

- Prior to the energy audit the Ops. Ctr. load was 100,740 kWh/year
- Following load reduction the total measured consumption for the Ops. Ctr. is 74,460 kWh/year
- Receptacle Load from Design Engineer's model for the Ops. Ctr. is 12,079 kWh/year, based on 3,000 sf
- Difference: 74,460 – 12,079 = 62,381 kWh/year, (addition load not in Original Model)

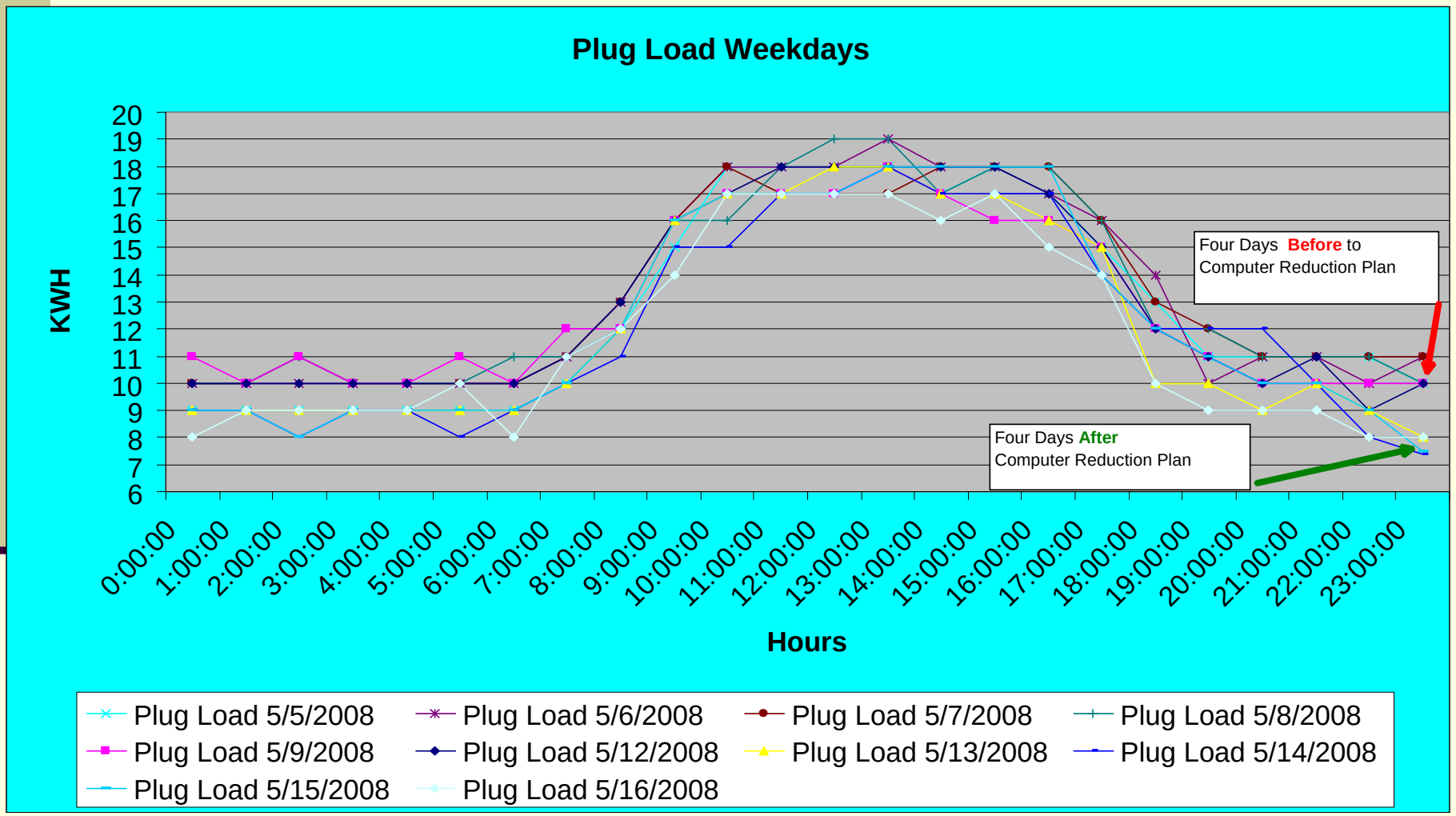
Text of the email sent to all Blackstone workstations on May 12, 2008

"Recently, the Blackstone Energy Audit Team was formed to evaluate the energy use and to develop reduction strategies for Blackstone, beginning with the South building. During the initial evaluation we discovered that many occupants are leaving their computer and monitors on during off hours. For example, yesterday (Sunday) we found 73 monitors and 43 computers were left on in the South building alone.

Starting today, we are requesting that all occupants completely shut down their computers and monitors when leaving for the day (with excepted workstations in the AT group that are required to stay on). You will receive email instructions to leave your computer on during evenings when UIS will be delivering a patch across the network. (However, you can still power down your monitor during the patch delivery.)

This small individual change has the collective potential to save up to 20,000 kWh of electricity annually. Thank you in advance for willingness to help conserve energy. We will keep you updated on other findings from the audit as they become available."

Daily Plug Load Trends
Before and After Computer Shutdown Notice



Power and Heat Load Savings Generated by Computer Shutdowns

The following illustrates the power and heat load reduction opportunity if 41 Desktop Computers and Monitors were completely shut down during unoccupied hours. The heat load of this equipment alone averages 0.77 tons per hour.

kWh Savings (day) by turning off Desktops	**65.30**
BTU/kWh (Heat Generated by Monitors)	3,412
Total BTU Heat (day)	222,804
BTU/Ton	12,000
Tons/hr	**0.77**
Ton/hrs (day)	18.57
Ton/hrs (year)	6,777