Dartmouth College
Campus Energy and Sustainability Management System

Quarterly Progress Report for
New Hampshire Greenhouse Gas Emission Reduction Fund

Reporting Period:
August 1, 2010 through October 31, 2010

1. **Program Title:** Campus Energy and Sustainability Management System (CESMS)

2. **Program Type:** The Campus Energy and Sustainability Management system will reduce energy use and associated greenhouse gas emissions at Dartmouth College by using a web-based interface to track, report, and optimize building energy performance. The project supports items **5, 7, 8, 10 and 11** in the Public Utilities Commission's Request for Proposals issued February 23, 2009.

3. Overview of Progress During the 4th Quarterly Reporting Period:

3.1. Planning

3.1.1. **Functional Requirements Specification (FRS) Development:** Final details were settled in the FRS during the 4th quarterly reporting period. The system reporting structure and format of sustainability indicators, energy alarm routines, utility billing data outputs and aggregation of meter data is now determined. See Exhibits 1 and 2.

3.1.2. **Meter Automation Plan**– The metering automation plan was updated during the quarter to reflect ongoing minor changes required at the field level. Planning for installation of 17 electrical submeters for the Tuck GreenLite project, described in Section 3.18, below, was completed, including preparation of detailed plans and specifications and a bid package for contractor installation. See attached Exhibit 3 for the latest Diagram of the entire Campus Metering Automation Plan, revised to reflect the above additions/deletions.

3.1.3. **Metering Automation Equipment –** There were no substantial changes to metering automation equipment during the 4th Quarter.

3.1.4. **Server Software** – Rockwell is running both a Development and a Production version of their VantagePoint software on system severs. The Development version is being used to try out an Advanced Type Modeling structure for BMS points, and the Production version is being used as the main daily tool for system trending and publishing of reports. Separate servers are being used for collection of Energy Metering data (RSEnergyMetrix). Another server (Rockwell FactoryTalk Historian) will be used for the collection and storage of Heating/Electric Plant data (planned for installation during the 5th Quarterly Reporting period). See Exhibit 4 for diagram indicating the Campus Energy and Sustainability Management System Server Hardware/Software configuration.

3.1.5. **Connection to BMS Systems** – Connection to the Honeywell and Johnson Controls BMS Systems is completed. We are currently structuring data point collections for HVAC equipment into an Advanced Type Modeling structure

within the Rockwell VantagePoint platform in order to make the systems easy to find and view on a "tree structure" and for automated fault detection routines to be run using user-scripted rules.

3.1.6. **Connection to Heating/Electrical Plant SCADA Systems –** Plans for connection to data points in the Heating/Electrical Plant are finalized. Our plan is to install the server and data historian software during the upcoming December (2010) break period. ABB, our Heating/Electric plant process control vendor will set up a data point server on the process control side and then Rockwell Automation will install a FactoryTalk Data Historian on the Campus Energy & Sustainability Management System side of the project. This will keep the two worlds separate, yet gain us real-time access of energy-production data (#6 fuel oil flows into each boiler, pressures, temperatures, cogeneration electrical production, main steam production and steam flows out to the campus, etc.)

3.1.7. **Energy "Tiger Team"** - Our "Tiger Team" continues to meet with the campus Energy Program Manager on a regular basis. The meetings are held on weekly basis, to address operational issues that are being detected via the Campus Energy and Sustainability Management System (CESMS). As a result of these meetings, we have turned our attention to Berry Library, our single largest energy consuming building. Using the CESMS as an essential discovery and trending tool, we have embarked on a program of recommissioning the main air handling systems and terminal air volume control systems for the building. We have discovered that the outdoor air damper control actuators are broken or are in serious disrepair which has resulted in excessive use of outdoor air, preheat (steam), and cooling (chilled water) --- See Exhibits 5 & 6 for Examples of AHU-3 and 4 Operating Issues.

From this knowledge, we have established a plan to install a new air sensing and control system (Aircuity) which will much more accurately detect and signal the required levels of ventilation for each air handling system. We are also planning for the replacement of all the main ventilation damper actuators with precise electronic control devices. We have also commissioned a consulting engineer to review and re-specify minimum ventilation flow rates for each of the building's 5 main air handlers and for each of the building's 230 variable air volume boxes. The main air handling project work will be done during the 5th quarterly reporting period and the zone level sensing and VAV rebalancing will be done during the 6th quarterly reporting period. We will also continue to meet to discuss further issues on other major energy using buildings.

3.1.8. **Beginning of Formal Academic Collaborative** – During the 4th Quarter, we began our formal relationship with the Tuck School of Business and Lorie Loeb, Research Associate Professor in the Computer Science department. During this period, we installed 17 new electrical sub-meters on the electrical services serving the 7 residential spaces located within the Tuck LLC and Whittemore Hall buildings. Provisions were also made for installation of 7 HP TouchSmart PanelPCs on the walls in the common spaces for each of these living areas. (Costs for all of this work will be covered under a separate gift from the most recent Tuck School graduating class with supplemental help by the Tuck School administration). These systems will be energized during the 5th Quarterly reporting period. The intent is for the residents to be able to see the impact of

their individual energy use on the collective use of the floor, thereby resulting in positive behavioral changes. The GreenLite Dartmouth project will provide programming and compelling graphic displays for the PanelPC locations to encourage use of these energy-feedback systems. There GreenLite display system features a "competition mode" as well as other interesting features.

The systems will be the subject of an academic study to monitor the results of real-time energy feedback. We will incorporate the results of this closely-controlled project into the actions of our ongoing CESMS work.

3.2. Execution

3.2.1 Execution of Task 1 through Task 3 items continued during the 4th quarter reporting period. Activities principally involved Task 1 items related to meter automation by Dartmouth's internal Trade Shop labor force. We have made good progress in meter automation, now being able to see greater than 95% of the campus electrical load and approximately 85% of campus steam load. At this point, all of the high priority (top energy using buildings) have had their meters automated. In some instances in the tables below, the % complete values are subjective rather than quantitative due to differences in the line item descriptions between the budget prepared and submitted by Dartmouth with its RFP submission and the listing of Tasks prepared by the NHGHGER Fund. These tables are presented to indicate general progress in each of the task areas. The Detailed Cost vs. Estimated Budget form attached as a PDF file, presents the financial comparison between the project budget and the 4th Quarter costs.

3.2.2 A summary of Task 1 Progress follows:

Task 1: Connection of Dartmouth College Facilities to the System.		**% Complete**
Subtask 1.1:	Automate meters for all buildings and connect them to the system.	85%
Subtask 1.2:	Connect to BMS and Boiler Plant systems for real-time efficiency monitoring.	75%
Subtask 1.3:	Link live weather feeds and 24-hour energy projections by meter.	100%
Subtask 1.4:	Develop real-time energy alarms (actual use vs. projected use)	20%
Subtask 1.5:	Install Sustainability Indicators.	50%
Subtask 1.6:	Develop Building Performance Metrics (actual vs. design).	30%

3.2.3 A summary of Task 2 Progress follows:

Task 2: Feedback, Behavioral Change, and Education & Outreach.		**% Complete**
Subtask 2.1:	Connect energy data from dormitories into the energy feedback display system and add additional feedback displays to buildings on campus.	35%
Subtask 2.2:	Evaluate the impact of feedback and connected	0%

	social networking tools on occupant behavior through separate research-funding.	
Subtask 2.3:	Conduct outreach to students, staff and faculty about recommended conservation measures.	0%
Subtask 2.4:	Develop case studies in areas where occupant behavior accounts for a relatively high proportion of total building energy use.	0%
Subtask 2.5:	Share findings with state officials and colleagues.	0%

3.2.4 A summary of Task 3 Progress follows:

Task 3: System Monitoring, Verification and Reporting.		**% Complete**
Subtask 3.1:	Ensure that the meter automation program provides accurate results.	70%
Subtask 3.2:	Establish a rigorous program to verify the polled data from the building management systems.	60%
Subtask 3.3:	Set target energy reductions on a building-by-building basis once building energy baseline performance has been established.	15%
Subtask 3.4:	Monitor the financial expenditures and performance of the program.	20%
Subtask 3.5:	Use the system to assess the effectiveness of behavior change campaigns and social learning experiments	10%
Subtask 3.6:	Share the results of the measurement and verification program in an annual summary report.	0%

4. Work to be Completed During the Next Quarter:

4.1. Planning

4.1.1. **Facilities/Academic Collaboration:** We will finalize the details of the Tuck GreenLite collaboration to monitor the impact of real-time energy displays for the Business School residential living facilities (See Exhibits 7 & 8 for examples of graphic screen concepts developed by the GreenLite team for the upcoming metering project). Control, experimental and competition groups will be set up between the 7 new monitoring and display locations. Our plan is to develop case studies for these buildings where occupant behavior accounts for a relatively high proportion of total building energy use.

4.1.2. **Heating/Electric Plant Monitoring Points:** We will install the equipment and software for integration of Heating and Electric Plant energy monitoring points into the CESMS. The points will be used to determine the energy inputs on the supply side of steam and electric production and for determining overall system energy efficiencies.

4.1.3. **Fault Detection Algorithms:** We will continue working with Rockwell on development of fault detection algorithms that will analyze energy system performance in the background while we are using the system for other functionality. The result will be a series of exception reports targeted specifically at the systems which appear to be operating inefficiently according to rules which we develop and input to operating models of various system types.

4.1.4. **Semi-Manual Data Inputs:** We will finalize the upload data set configurations that will allow us to capture not only the automated meter data but the ongoing historical record of other energy or resources used or disposed of by the campus. Examples include stand-alone electrical meters (non-automated off-campus meters), fuel oil, propane and diesel fuel drops, water and sewer use, gasoline use, solid waste, recycling, composting, etc. We will also create an upload data set that includes all of the on-campus building-by-building energy use history for steam, electric and chilled water dating back to 1982.

4.2. Execution

4.2.1. **Metering Automation:** Continue automating the remaining approximately 40 metering locations, picking up the remaining electrical, steam and chilled water meters.

4.2.2. Establish Building Energy Baselines: We will continue developing building energy baselines as additional building energy meters are brought on line during the 4th quarterly reporting period **(See Exhibit 9 for Energy Prediction vs Actual Use at Remsen Hall)**

4.2.3. **Connection to Heating/Electrical Plant SCADA Systems:** We will complete connectivity to the Heating and Electrical plant control system data via an OPC server and a Rockwell FactoryTalk Historian.

4.2.4. **Refine Efforts of Energy "Tiger Team":** We continue with our energy "Tiger Team" meetings and will set several recommissioning projects into action. These will include:

- Recommissioning of individual building CHW distribution system controls to improve overall Central Chiller Plant differential temperatures
- Recommissioning of the large air handling systems serving the Berry Library complex. As part of this work, we will use the CESMS to help rebalance several hundred variable air volume boxes to lower minimum flows. Currently the minimum settings are relative high, causing spaces to overcool during lower load periods..

4.2.5. Kiosks: We will continue detailing content for the building-level energy display kiosks.

4.2.6. **Implementation of Additional Sustainability Indicators:** We are beginning to provide web-based visual displays for tracking Sustainability Indicators on the CESMS. These include GHG's, solid waste, recyclables and water use. Methods for easily inputting data into the CESMS will continue to be developed during the 4th quarterly reporting period.

4.2.7. **Fault Detection Software**: We will roll out fault detection software as part of the CESMS for background monitoring of system energy performance. We have included high energy-use systems such as the Berry Library complex as part of a the first roll-out.

5. **Jobs Created** – No additional jobs were created from this project during the 4th quarter reporting period.

6. **Obstacles Encountered** –

6.1.1. **Meter Automation Labor** – Labor costs for automation of the metering infrastructure is running over our original budget, partially due to the degree of difficulty encountered in setting up the wireless infrastructure and partially due to having added a number of meters to the automation list. We are committed to completing the process because it is essential to the successful outcome of the project and will provide other important business benefits to the College.

7. **Beyond the Contract** – Rockwell Automation has continued a keen interest in our project and, is using the Dartmouth Vision Client relationship to help them develop new input and output strategies, including use of the data for automated fault detection services.

8. **Related Materials –** The Campus Energy and Sustainability Management System is currently being utilized to track the energy collection capabilities of the new Solar Domestic Hot Water preheating system installed in the early summer at the Sustainable Living Center. We also completed installation of another solar DHW preheating system, this time for the College President's house. This, too, will be monitored via the CESMS.

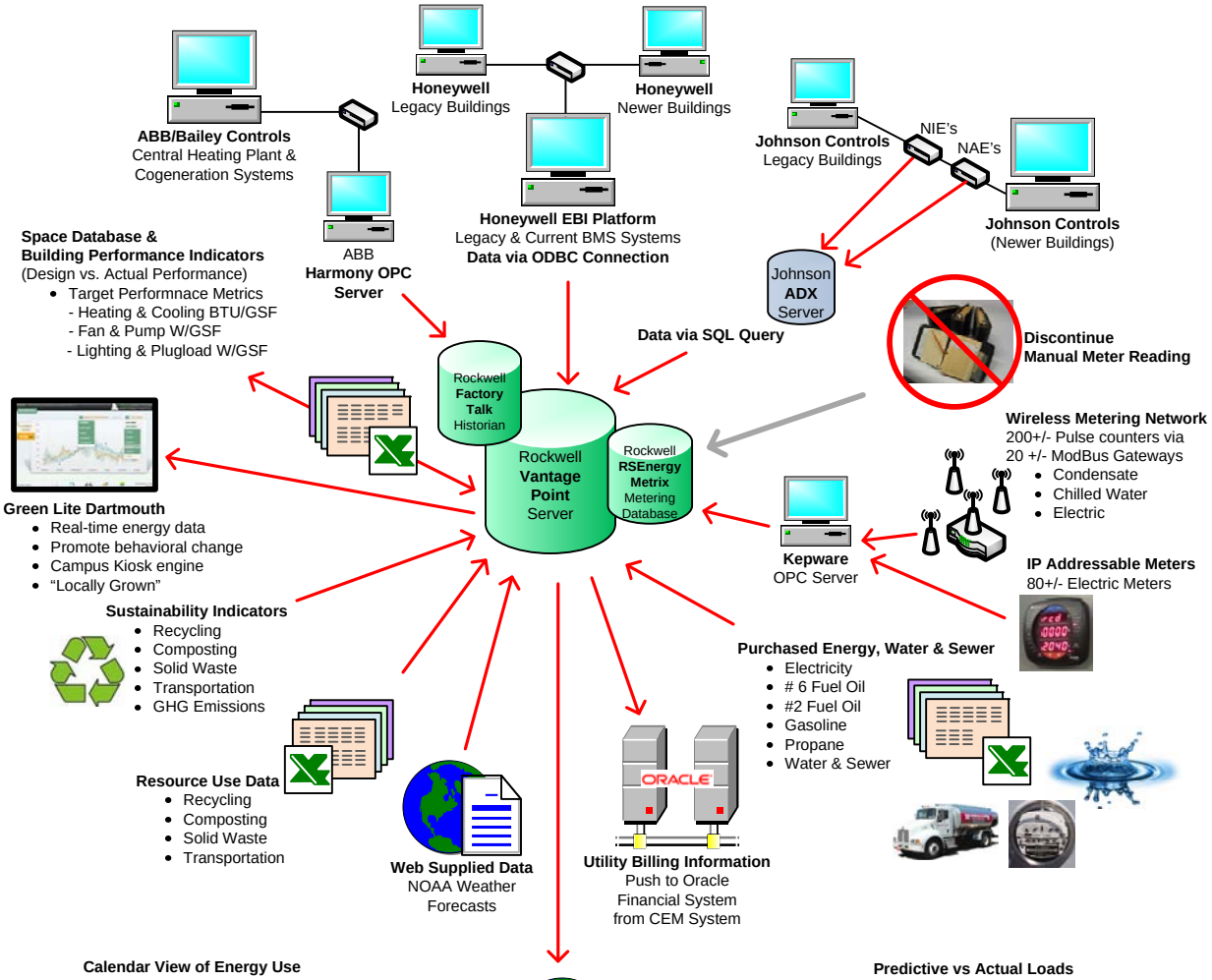
Respectfully submitted,

Stephen R. Shadford, P.E., LEED AP
Dartmouth College
Energy Program Manager and Principal Investigator for NHGHGER Fund Grant Project

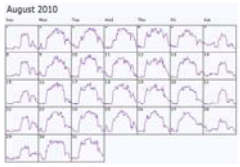
Attachments – Exhibits 1 through 9

Exhibit 1

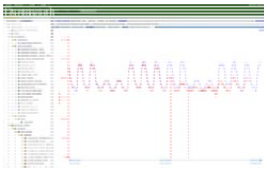
Dartmouth College
Campus Energy & Sustainability Management System
System Overview



Calendar View of Energy Use



Predictive vs Actual Loads

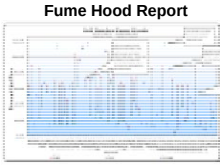


Web Published Data

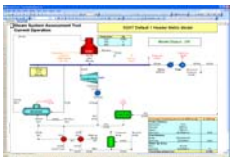
Standard & Customized Management Reports Generated via Excel Spreadsheets and System Portal

- Energy Management
- Detailed system analysis
- Historical Equip. Use Profiles
- 24 Hr Forward Load Projections
- Continuous Htg/Elect Plant Eff.
- Energy Purchase Hedging
- "Customer" Use & Billing History
- Energy Use Alarms (e-mail, etc)
- Billing Rate Calculations
- Sustainability Management
- GHG Reporting
- Carbon Asset Accounting
- Dashboard Views of System Performance
- Building Performance Metrics
- Title 5 Emissions to YTD

Fume Hood Report

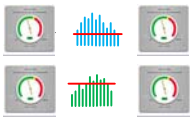


Heating/Electric/CHW Plant Efficiency



Utility Rate Engine

Sustainability Indicators



Building Performance Indicators

Greenhouse Gas Accounting

Revision 2.0
1/11/11
SRS

Exhibit 2

Dartmouth College
Campus Energy & Sustainability Management System
Energy and Resource Data Inputs and Outputs

Off-Campus Buildings & Misc. On-Campus Resource Use

Heating/Electric Plant

Main Electrical Utility Feeds

Main Campus Buildings

Local
Boilers, heating sources, electrical metering, water metering, etc
Resource use data via flat file uploads to VantagePoint

Metered #6 Fuel Oil Consumption
Boilers 1 thru 4 via ABB Harmony OPC Server

CoGen Electrical Production
TG 1 thru 3 via Kepware ModBus Poller

Automated Metering of Utility Electrical Services for Central, North, & West Campus via Kepware ModBus Poller

Automated Metering of Building Energy Consumption
Steam, Elect & CHW via Kepware ModBus Poller

Exhibit 1 — **Quarterly Water and Sewer Use** (Quarterly Flat File from **Hanover Water Company**)

Exhibit 2 — **Monthly Oil, Propane & Diesel Deliveries** (Monthly Flat File from **Irving Energy**)

Exhibit 3 — **Monthly Fleet Gasoline** (Monthly Flat File Compiled by **Dartmouth Facilities** from Evans Energy statement)

Exhibit 4 — **Consolidated Electrical Account Summary** (Monthly Flat Files from **TransCanada** and **National Grid**)

Exhibit 5 — **Monthly Waste Streams** Recyclables,Composting, Solid Waste to Land Fill, etc. (Monthly Flat File Compiled by **Dartmouth Facilities**)

Future

Exhibit 6 — **Travel Data** VOX Fleet Fuel, Commuting Fuel & Air Travel (Monthly Flat File Compiled by **Dartmouth Facilities**)

Exhibit 7 — **Refrigerants and Chemicals** (HFC's and Chemicals Monthly Flat File Compiled by **Dartmouth EH&S and Facilities**)

Note:
For data and reports, above, some Buildings are on Central Campus and some buildings are Off-campus

Wizard(s) for Data File uploads by Admin. Staff

Common Tag = Building ID.

Rockwell **FactoryTalk Historian**

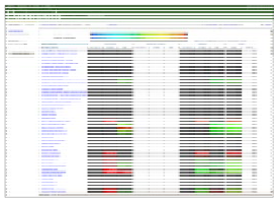
Rockwell **RSEnergy Metrix** Metering DB

Rockwell **VantagePoint** Server

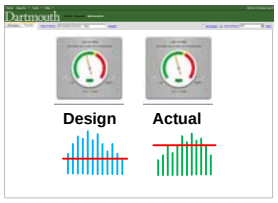
Reports & Dashboards

Reports & Dashboards

All Building Summary



Building Performance Metrics



Historical Energy & Resource Use

Utility Billing

In Development

Rate Engine

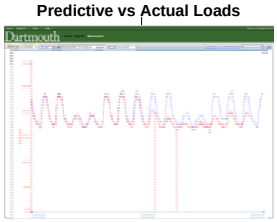
In Development

Greenhouse Gas Accounting

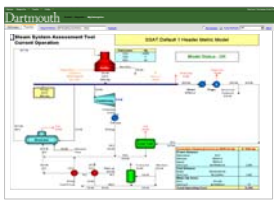
ORACLE

Chart String Account Charge Table to Oracle Financial System

Predictive vs Actual Loads



Heating/Electric/CHW Plant Efficiency



Revision 2.0
1/11/11
SRS

Exhibit 3

Dartmouth College
Metering Automation Plan

Rev. 1.9

8/25/10

LEGEND

- SpinWave Zone XX — SpinWave Gateway Device (Modbus TCP) XX = SpinWave Zone No.
- E0101 SXX — SpinWave Wireless Pulse Transmitter
- E4321 — Existing IP Addressable Electrical Meter On-Line
- E0101 — Existing IP Addressable Electrical Meter Not Yet On-Line
- E1234 — New IP Addressable Electrical Meter Not Yet Installed
- E1234 — Possible New IP Addressable Electrical Meter. Check if Needed.
- E1234 — Field Investigate Type of Existing Meter

REVISION NOTES

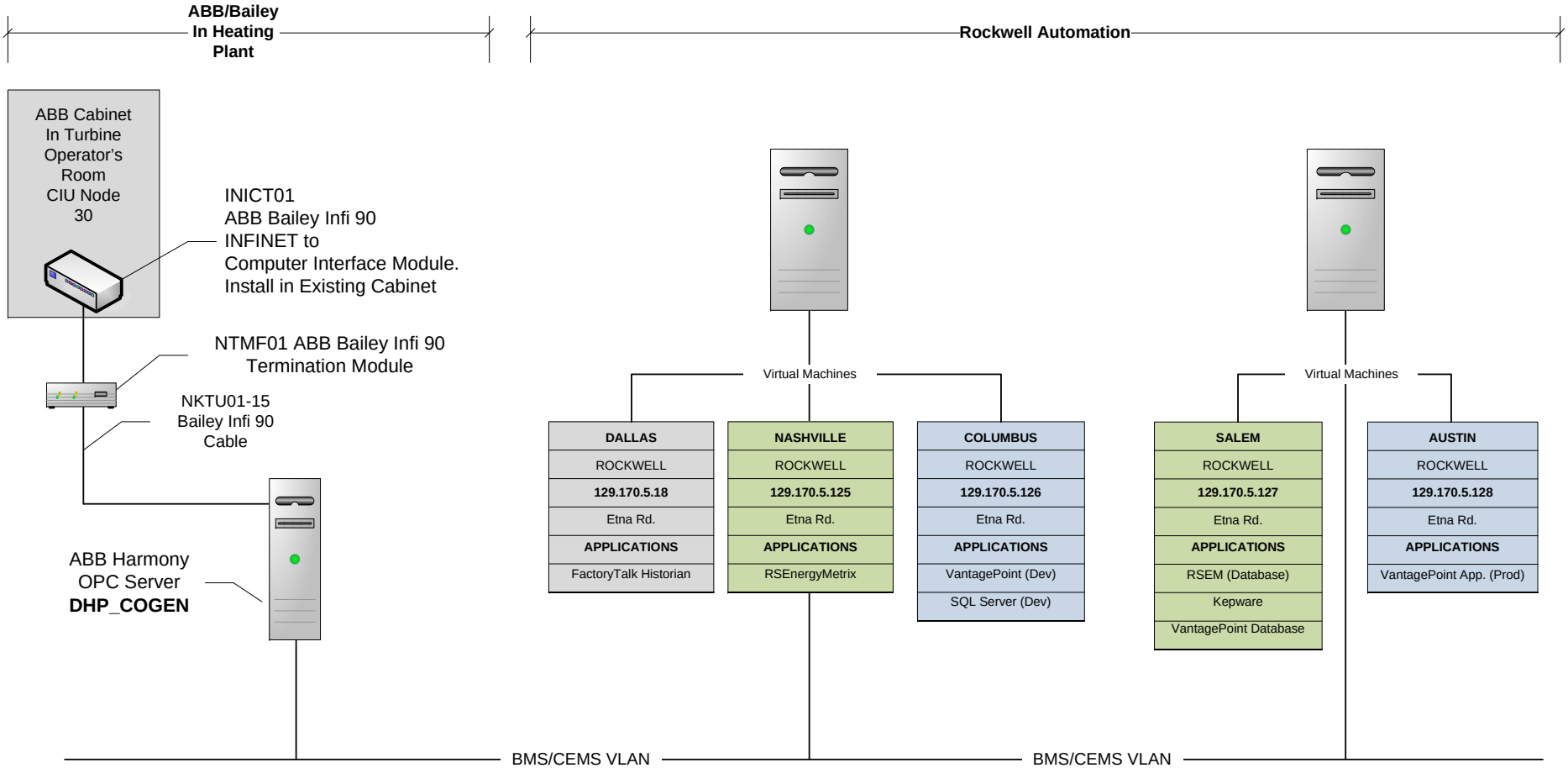
Rev.	Date	Change
1.1	2/1/10	Deleted Hood Annex .E0021A (Removed)
1.2	2/2/10	Deleted Hood S0116B Cond. Meter (Unused)
1.3	2/3/10	Deleted Htg. E0577 Plant Maint. Shop (Bldg to be Demolished)
1.4	2/11/10	Moved Spinwave Gateway #19 from Mid Mass to Thayer Dining
1.4	2/11/10	Moved Spinwave Gateway #13 from Thompson to Boss Tennis
1.5	5/31/10	Moved Spinwave Gateway #13 from Boss Tennis to Thompson
1.5	5/31/10	Added Central, North and West Main Campus Feeders (5)
1.5	5/31/10	Added 3 Turbine Generator Meters
1.5	5/31/10	Added Emergency Generator Meter at McKenzie/Htg Plant
1.6	8/6/10	Deleted Gateway for Zone 4. Devices will be part of Zone 10
1.7	8/10/10	Changed E0135B from Spinwave to IP meter (Existing ION)
1.8	8/23/10	Tuck GreenLite - Added 9 Sq D Enercepts for Tuck LLC
1.8	8/23/10	Tuck GreenLite – Added 8 Sq D Enercepts for Whittemore
1.9	8/25/10	Changed E0088 Buchanan from Spinwave. Now new SqD PM820
1.9	8/25/10	Divided Tuck metering Zones into Zone 12 and Zone 4.
1.9	8/25/10	Added Gateway Zone Location Table, below.
1.9	8/25/10	Updated I/P Meter Symbols to Current Conditions

SPINWAVE ZONES

Zone #	Gateway Location (Bldg)	Gateway Location (Within Building)
1	North Hall (SLC)	Basement Electrical Room
2	Moore Psychology	Adjacent to LAN Closet
3	Berry Library	LAN Closet behind Info Desk
4	Chase Hall	TBD
5	Fairchild Physical Sci.	Basement Level LAN Rm 006
6	Vail Hall	Ground Floor Data Room
7	McKenzie Hall	LAN Closet in Plumbing Shop
8	Hopkins Center	LAN Closet Lower Level Hallway
9	West Gym	LAN Room adjacent to Main Sw. Gear Rm.
10	Central Chilled Water Plant	Chller Plant Control Room
11	Russell Sage	TBD
12	Whittemore Hall	Rm 014
13	Thompson Arena	Ticket booth
14	Dana Library	Basement Entrance
15	37/50 Dewey Field Road	TBD
16	McCulloch Hall	TBD
17	Gile Hall	TBD
18	Dartmouth Hall	Room 320
19	Massachusetts Hall Middle	Trunk Storage Room
20	MacLean Engineering Sci. Ctr.	Basement MER

Exhibit 4

Campus Energy and Sustainability Management System
Server Hardware and Software Configuration



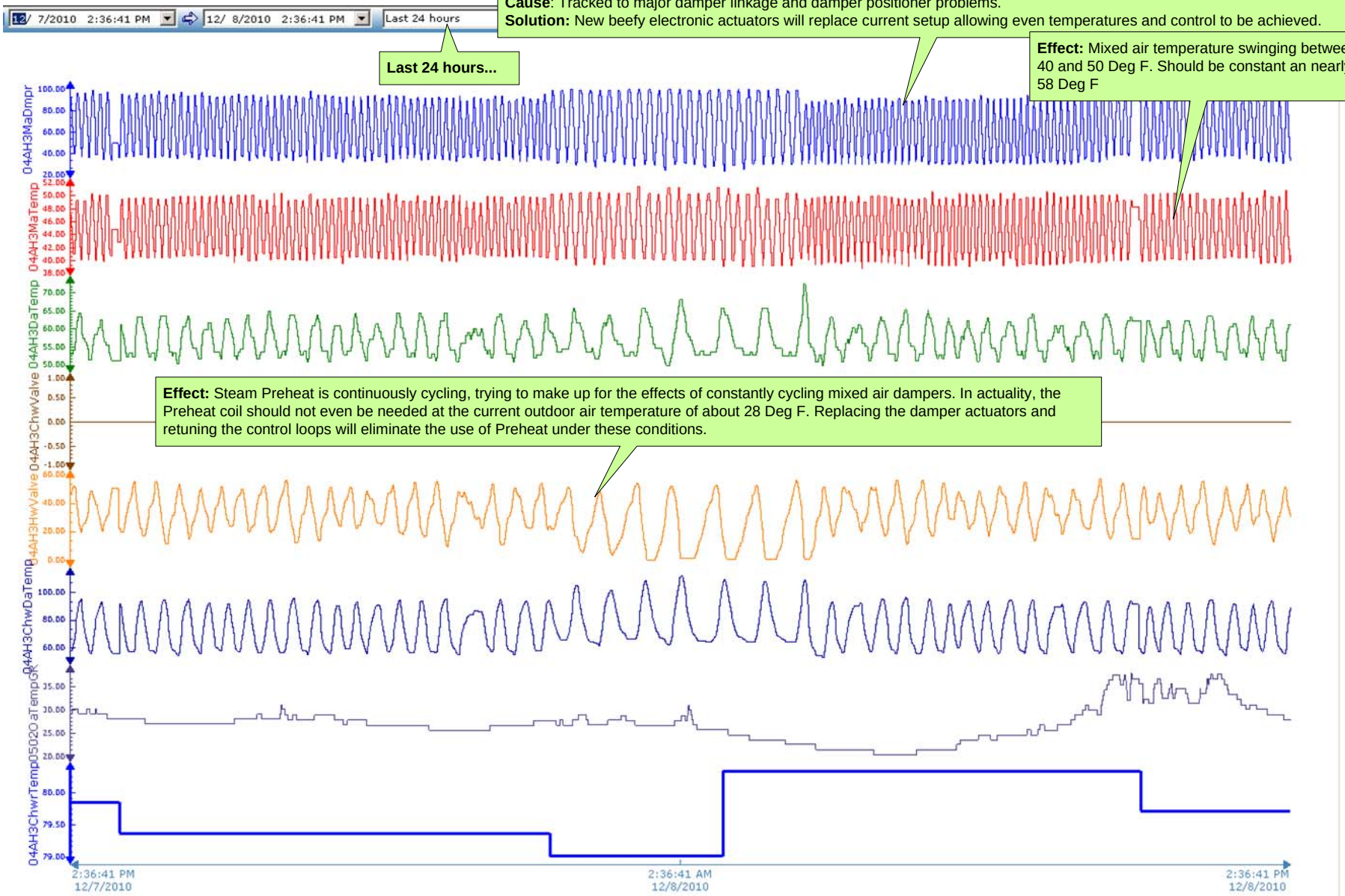
Berry Library AHU-3 12/8/10

Problem Identified: Continuous cycling of damper controls identified by Campus Energy Management System. Wildly cycling dampers are causing the system to need preheat energy when, if controlled properly, it would otherwise NOT be necessary.
Cause: Tracked to major damper linkage and damper positioner problems.
Solution: New beefy electronic actuators will replace current setup allowing even temperatures and control to be achieved.

Effect: Mixed air temperature swinging between 40 and 50 Deg F. Should be constant an nearly 58 Deg F

Last 24 hours...

Effect: Steam Preheat is continuously cycling, trying to make up for the effects of constantly cycling mixed air dampers. In actuality, the Preheat coil should not even be needed at the current outdoor air temperature of about 28 Deg F. Replacing the damper actuators and retuning the control loops will eliminate the use of Preheat under these conditions.



Tag	↓..	/..	Description	Style	Min (A)	Max (A)	Unit	Precision	Format	Source	Tag Min	Tag Max	Retrie...	Y Delta
...ywellDDC.04AH3HwValve	5	☑	BryBkr AHU3 Hot Water Valve ...		-5.599613	63.0248...		2	Decimal		0	100	Delta	
...llDDC.04AH3ChwDaTemp	6	☑	BryBkr AHU3 Chw Coil Da Temp ...		47.7037...	117.430...		2	Decimal		0	150	Delta	
...wellDDC.0502OaTempGR	7	☑	AlumGym Oa Temp ...		18.8784...	39.5369...		2	Decimal		0	100	Delta	
...ellDDC.04AH3ChwrTemp	8	☑	BryBkr AHU3 Chw Ret Temp ...		78.88781	80.46829		2	Decimal		0	150	Delta	

Berry Library AHU-4 12/8/10

Problem Identified: Continuous cycling of damper controls identified by Campus Energy Management System. Wildly cycling dampers are causing the system to need preheat energy when, if controlled properly, it would otherwise NOT be necessary.
Cause: Tracked to major damper linkage and damper positioner problems.
Solution: New beefy electronic actuators will replace current setup allowing even temperatures and control to be achieved.

Last 24 hours...

Effect: Mixed air temperature swinging between 40 and 50 Deg F. Should be constant an nearly 58 Deg F

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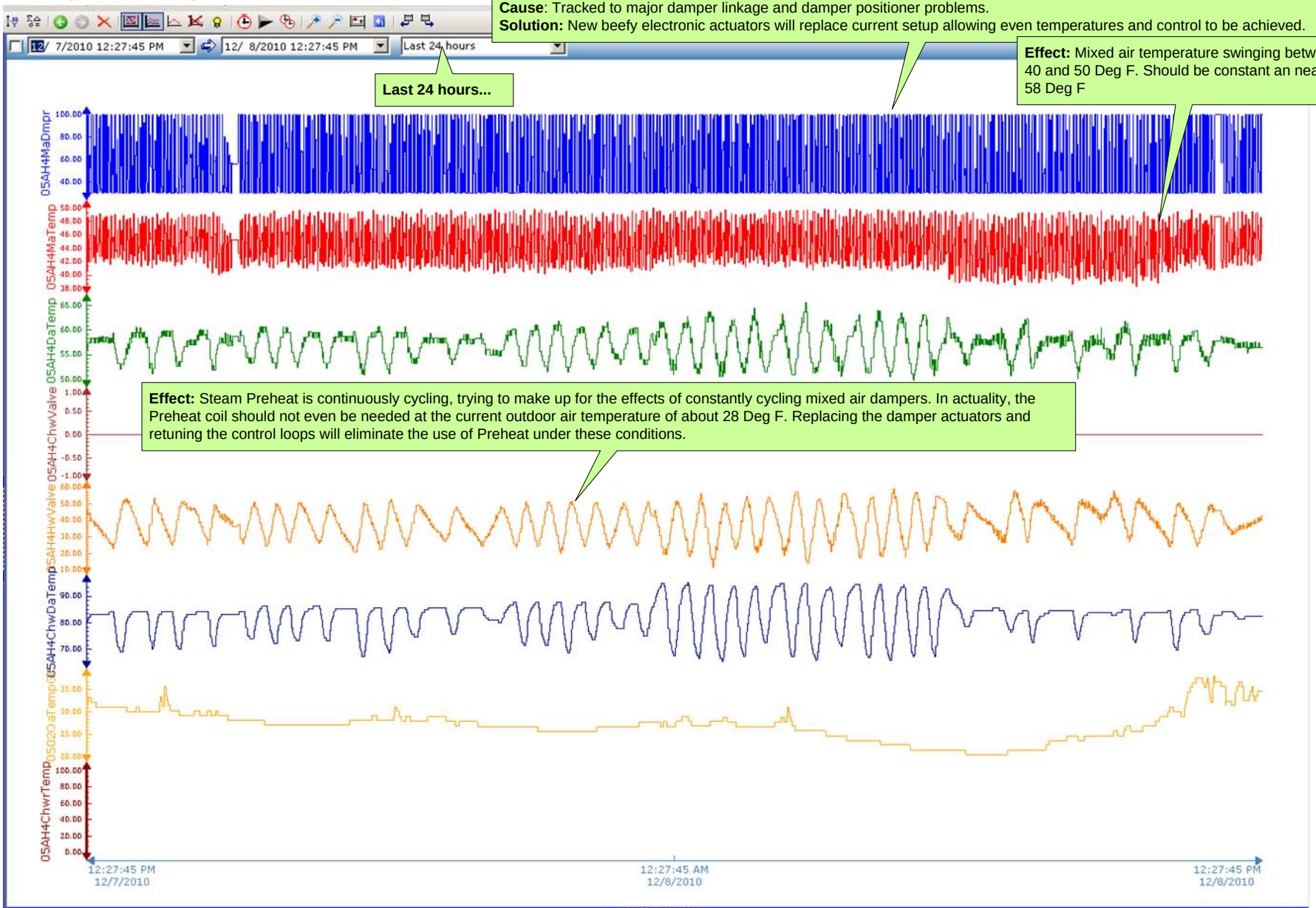

Tag	Description	Style	Min (A)	Max (A)	Unit	Precision	Format	Source	Tag Min	Tag Max	Retrie...	Y Delta
...ywellDDC.05AH4MaDmpr	BryBkr AHU4 Mixing Dampers		23	107		2	Decimal		0	100	Delta	
...ywellDDC.05AH4MaTemp	BryBkr AHU4 Ma Temp		37.15967	51.12055		2	Decimal		0	100	Delta	
...ywellDDC.05AH4DaTemp	BryBkr AHU4 Disch Temp		48.2917...	67.2478...		2	Decimal		0	100	Delta	
...wellDDC.05AH4ChwValve	BryBkr AHU4 Chw Coil Valve		-1	1		2	Decimal		0	100	Delta	

Exhibit 7

Mock-up of "Polar Bear" Animation Screen Display to be Deployed at Tuck Living Learning Center and Whittemore Hall

Exhibit 8

Mock-up of "Polar Bear" Energy Graph Screen Display to be Deployed at Tuck Living Learning Center and Whittemore Hall

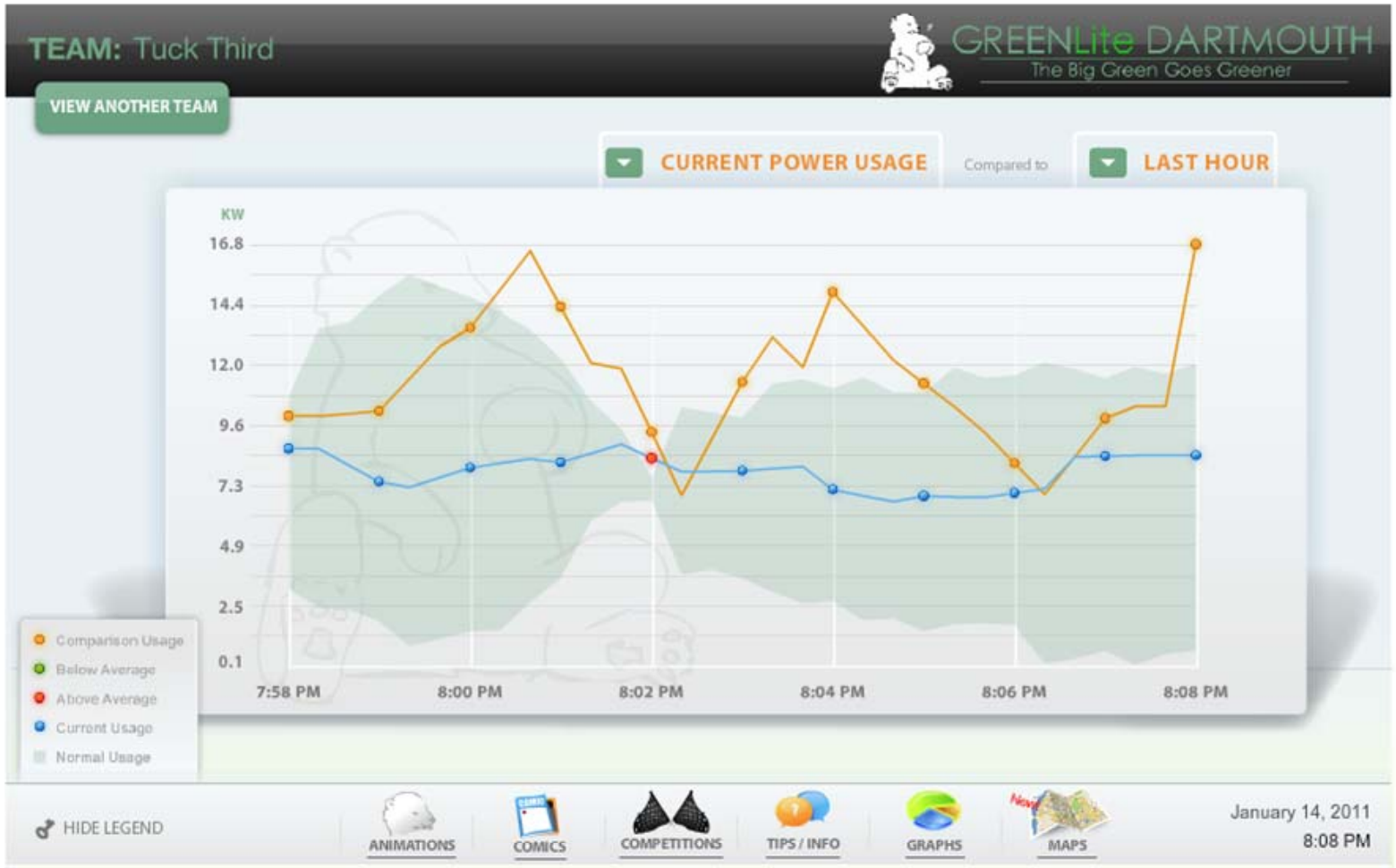

Exhibit 9

Remsen Hall – Predicted vs Actual Loads (kW)