Dartmouth College
Campus Energy and Sustainability Management System

Quarterly Progress Report for
New Hampshire Greenhouse Gas Emission Reduction Fund

Reporting Period:
May 1, 2010 through July 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 3rd Quarterly Reporting Period:

3.1. Planning

3.1.1. **Functional Requirements Specification (FRS) Development:** Further details were added to the FRS during the 3rd quarterly reporting period that define the reporting structure and format of sustainability indicators, energy alarm routines, utility billing data outputs and aggregation of meter data..

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 to ensure that wireless meter transmission data would be successfully sent and received. Several meters were added and deleted to the previous list to reflect ongoing activities on campus including the addition of 17 electrical submeters for the Tuck GreenLite project, described in Section 3.18, below. See attached Exhibit 1 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 changed to metering automation equipment during the 3rd 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.

3.1.5. **Connection to BMS Systems** – Connection to the Honeywell and Johnson Controls BMS Systems is completed. We are currently putting the data points 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".

3.1.6. **Connection to Heating/Electrical Plant SCADA Systems –** Plans for connection to the Heating/Electrical Plant will be finalized and implemented during the 4th Quarterly reporting period. At the present, it appears as if we will

have ABB, our Heating/Electric plant process control vendor set up a data transfer computer on the process control side and then have Rockwell Automation install a FactoryTalk Historian on the Campus Energy & Sustainability Management System side of the project, thus keeping the two worlds separate, yet gaining 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 as we gain more visibility into energy systems. We have stepped up the frequency of these meetings to a weekly basis, to address operational issues that are being detected via the Campus Energy and Sustainability Management System (CESMS). Currently we are working to explore controls related with building-level chilled water distribution. Using the CESMS we are seeing fairly low system differential temperatures in our main campus CHW distribution loop. We are checking individual building level control loops to ensure that each building is performing properly. When this is complete, we will move to the Central Chiller Plant to check accuracy of staging sequences, flow rates and tonnage meters.

3.1.8. **Establishment of Academic Collaborative** – During the 3rd Quarter, we solidified a Facilities/Academic relationship between our Tuck School of Business and Lorie Loeb, Research Associate Professor in the Computer Science department. Lorie Loeb runs the GreenLite Dartmouth project, a real-time energy display system directed toward positive energy-behavioral changes.

In July, The Tuck School received a generous gift from their graduating Class of 2010 that is to be used for installation of real-time energy displays for the residential floors of Tuck's two main "living and learning" buildings (Whittemore and Tuck Living/Learning Center). A total of 17 new electrical sub-meters will be installed on the electrical services serving the 7 residential spaces located within these two facilities. In addition, a total of 7 HP TouchSmart PanelPCs will be installed on the walls in the common spaces for each of these living areas. When installed, these systems will provide real-time energy feedback to the residents of the floors. 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 installed and configured during the 4th quarterly reporting period and 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 3rd 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 90% of the campus electrical load (See Exhibit 2) and approximately 70% of campus steam load (See Exhibit 3). 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 3rd 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.	60%
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.	50%
Subtask 1.4:	Develop real-time energy alarms (actual use vs. projected use)	2%
Subtask 1.5:	Install Sustainability Indicators.	40%
Subtask 1.6:	Develop Building Performance Metrics (actual vs. design).	5%

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.	5%
Subtask 2.2:	Evaluate the impact of feedback and connected social networking tools on occupant behavior through separate research-funding.	0%
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.	40%
Subtask 3.2:	Establish a rigorous program to verify the polled data from the building management systems.	50%
Subtask 3.3:	Set target energy reductions on a building-by-building basis once building energy baseline performance has been established.	0%
Subtask 3.4:	Monitor the financial expenditures and performance of the program.	15%
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 plan the details of the Tuck GreenLite collaboration to monitor the impact of real-time energy displays for the Business School residential living facilities. Control and experimental 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 plan for the 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 are 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.

4.2. Execution

4.2.1. **Metering Automation:** Continue forward automating the remaining approximately 120 metering locations to pick up the remaining approximately 10% of electrical energy visibility and approximately 30% of steam visibility.

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.

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 complete several building energy and sustainability information kiosks. The first kiosk, previously installed and started up in Dartmouth's admissions office lobby (McNutt Hall) will be dedicated in early September. Additional kiosks are planned for the Tuck School of Business (part of the Tuck GreenLite project) Berry/Baker Library, additional dormitory buildings, and possibly Collis Student Center and the Hopkins Center for the Performing Arts.

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 are targeting high-energy-use systems in the Berry Library complex as part of a demonstration project.

5. Jobs Created – No additional jobs were created from this project during the 3rd quarter reporting period.

6. Obstacles Encountered –

6.1.1. **Central Heating/Electric Plant Connectivity** - We continue to work with our Purchasing Department securing competitive pricing for the dual-vendor approach to Central Heating/Electric Plant Connectivity. We are striving to achieve a reduction in the price of connectivity for this scope item.

6.1.2. **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** – We have been interviewed by Connected World Magazine for an article they are running on our Spinwave wireless metering implementation.

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 recently at the Sustainable Living Center. We are currently completing 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 3

Exhibit 1

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 2 – Electrical Energy “Visibility”

7,500 kW / 8,000 kW = 93%

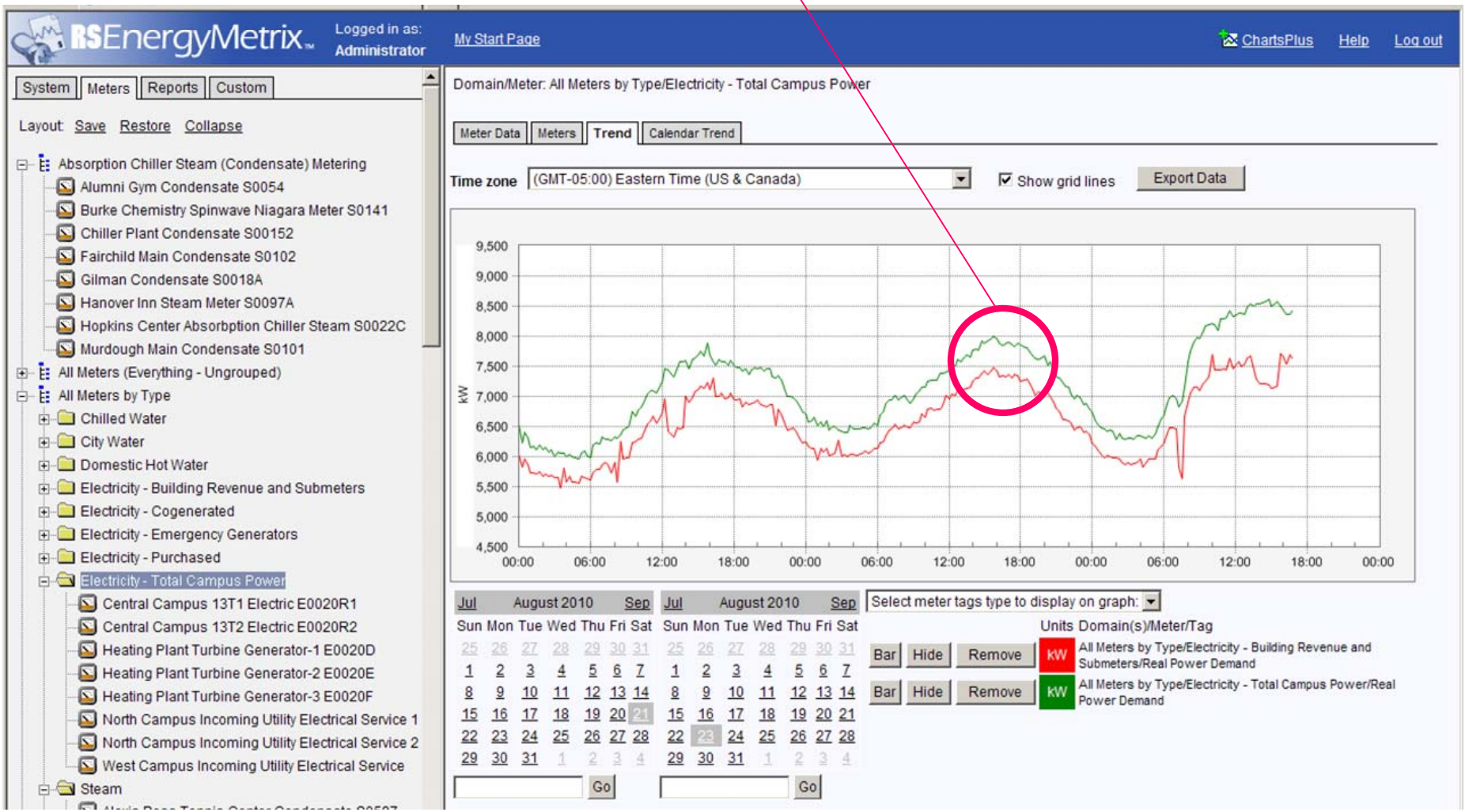

Exhibit 3 – Steam Energy "Visibility" from metering installations to date

For this example:

Total Steam Demand as seen through CoGen output: 2,600 kW * 27 # Steam per kW Generated = 70,200 #/Hr

Total Campus Steam Demand Visible to date via automated metering systems = 47,500 #/Hr

"Visibility" = 68%