SimBuild 2006

Second National IBPSA-USA Conference
Cambridge, MA
**August 2-4, 2006**

# BUILDING AS A LEARNING TOOL: FACILITY MANAGEMENT AND SIMULATION IN THE CLASSROOM

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## ABSTRACT

"Building as a Learning Tool" is a work in progress that uses a facility management portal that provides energy data from a building's electric and gas meters in an easy-to-read, near real-time, web-based format. The data are displayed on gauges that resemble those found on an automobile dashboard. This organization and manipulation of data never before possible aids in the rapid interpretation of a building's energy use, permits comparisons to simulations of how the building operates under different conditions, and provides an opportunity to assess the impact that changes or repairs to the building have on energy usage. In addition to improving building performance in the Newark Public School District, Building as a Learning Tool allows students to learn how a school building can and should perform under various operating conditions.

## INTRODUCTION

With a student population of 42,000, the Newark Public School District is the largest and one of the oldest school systems in New Jersey. The Newark Public Schools Facilities Management Office, which includes Design & Construction, Facilities Support, SLT Operations, and Project Control, has been working with the Department of Teaching and Learning and Schools to Careers toward a common goal to support the learning environment, maximize comfort conditions, and reduce energy use.

The use of the School "Building as a Learning Tool" was the underlying framework that connected the project using an "open source" Facility Management portal that lays the ground work for data sharing, ongoing discussions, and collaboration, to support all life-long learners (i.e., K-12 teachers, students, parents, administration, facility personnel, the architectural and engineering design community, contractors, equipment vendors, and manufacturers), as shown in Figure 1.

Answers to the following basic questions regarding operating parameters are often pursued reactively, after data are collected and analyzed and the time for action has passed: 1) How are buildings operating? 2) How much energy are the buildings using? 3) How much energy can the buildings save or should they be using? 4) How much energy are the buildings using compared to other buildings? 5) What can be done to improve building energy use now and in the future to make sure buildings are operating efficiently? Instead of answering these questions in a reactive fashion, the "Building as a Learning Tool" project also uses simulations to gauge building performance.

Typically, the utility bills for each school are sent to accounts receivable, paid, and filed. In contrast, "Building as a Learning Tool" uses the technology backbone of the school to provide the energy data from electric and gas meters, in the near real-time form of web-based data dashboards that include key energy performance indicators.

Concurrently with this metering and analysis, students working with the Facilities Department, architects, engineers, designers, and teachers can develop and utilize building energy simulations from AutoCAD drawings to illustrate how the building can and should perform under various operating conditions.

To initiate action, the Facility Department utilizes web-based work orders, direct digital control monitoring and control points, and personnel and equipment generated work orders to troubleshoot, correct and repair problems. Results of this work and lessons learned are shared via the district's Facility Management portal.

"Building as a Learning Tool" incorporates data from all of these departments to teach students about building performance through simulation. This technical presentation and project is a work-in-progress and lays the ground work for ongoing collaboration between these departments, teachers, and students.

## SIMULATION AND/OR EXPERIMENT

The Newark Public Schools represent a large school district with many buildings and elementary and high school students. In this school district, "Building as a Learning Tool" works at many different levels while connecting and providing access to existing and new data sources as well as departments and individuals, as shown in Figure 1.

Fundamentally, the school building is the experiment and the basis for simulation. The school building is used as a learning tool with the Facility Management portal providing the means of discussion and collaboration via the Internet, as shown in Figure 2.

The first building experiment chosen for the project was Belmont Runyon, the newest school building in the district. Belmont Runyon is an 116,000 square foot, PreK-5 elementary school completed in September 2004. The Facility Management portal provides fundamental building, metering, and energy data; utility bills for electricity and natural gas; excerpts from online utility databases; and near real-time data from energy meters. The project then builds on this basic electric (KWH) and natural gas (Therms) metering information with time-based performance metrics such as BTU/SF, KWH/SF, THERMS/SF, and a Facility Performance Indicator (FPI) metric that indicates an overall 0-100% value of how well the building is performing. This building dashboard and FPI metric, as shown in Figure 3, is especially useful when prioritizing which building in a district of many needs attention.

Prior to the initiation of this project, the district's Curriculum and Instruction Department already had an established CAD program, as shown in Figure 4. The existing program provides students with the opportunity to design on paper, as well as in AutoCAD, their own buildings and model homes, as seen in Figures 5 and 6. To help familiarize middle and high school students with energy efficiency and renewable energy systems, the "Building as Learning Tool" project included hands-on learning opportunities through field trips, use of mobile energy labs, video conferencing, and television documentaries, as shown in Figures 7 and 8.

The Newark Public Schools' Design and Construction Department already had experience with sustainable design and high performance buildings. Construction of several of these buildings is now under way as part of a massive school building program in New Jersey. The "Building as a Learning Tool" project at Belmont Runyon will also provide an opportunity for "lessons learned" on the last building constructed in the district.

The District's Operations and Maintenance Department has been implementing an online work order system for scheduled and preventive maintenance as well as a utility tracking database. Most recently, a project began to provide metering upgrades from the utility company to allow for real-time pulse signals to embedded devices connected in each building to the district's LAN/WAN, as shown in Figure 9.

The "Student" view within the Facility Management portal is shown in Figure 10. Students have the ability to change the web portals section that has been made available for their use on this project. The work area includes sections for analysis, discussion, and collaboration. This work area allows for connections between Newark Public Schools Facility Design and Construction, Operations and Maintenance, Curriculum and Instruction Departments as well as other collaborations within the learning community.

## DISCUSSION AND RESULT ANALYSIS

As previously indicated, the "Building as Learning Tool" project started with Belmont Runyon, the newest school in the Newark Public Schools District, as shown in Figure 11.

We are still at the beginning of this project, working to answer the basic questions of 1) How is Belmont operating? 2) How much energy is Belmont using? 3) How much energy can be saved, or how much should Belmont be using? 4) How much energy does Belmont use compared to other buildings? 5) What can we do to make sure that Belmont is operating efficiently now and in the future?

To answer these questions the project began with reviewing the data from an online energy tracking system, which is based on a manual data entry process. The results for the electric account as shown in Figure 12 show that there are data entry errors and missing data. This is typical for most school districts in which the utility data is received and paid in the accounts payable department.

Since the utility data available in the online database was not accurate and needed verification, it became necessary to collect the historic utility bills. This was a very time-consuming, frustrating process that continued with gaps and missing bills as shown in Figure 13. It was necessary to reach out to the utility company directly to obtain the missing data. This data will be

used to correct entries in the online bills in the database. Results from this analysis are also available in the FM portal to document this process and findings.

To improve accuracy and deal with missing data and estimated bills on an ongoing basis, an automated process was developed to obtain and process readings from the electric and natural gas meters shown in Figure 1. Working with the utility company, as shown in Figure 9, pulse output meters were installed. Each contact closure represents energy use in kilowatt hours or therms over any period of time. To get the data from the building to an energy server required a dedicated network drop, and a local embedded Ethernet device assigned a static IP address in the building. This device counts contact closures and makes the data available over the LAN/WAN, back to a central communication unit (CCU) that aggregates and stores instantaneous values from many meters and buildings.

The CCU stores these meter values in an XML file and periodically sends the data (via FTP) to a dedicated rack-server running MySQL and application programs to store, archive, report, and share information with the Facility Management portal. Working with the District's IT Department to make an external Internet IP address available with connections to the CCU also was an issue, especially in light of the recent increase in computer viruses. A demilitarized zone was established to allow the data to be shared to an external database, web server, and Facility Management portal.

By making energy data available from electric and gas meters on a timelier basis (i.e., changing from 45 to 60 days to 45 to 60 seconds using the technology backbone of the school), decisions can be made in time to directly impact the monthly and annual energy use.

The web-based data dashboards developed for this project include key energy performance indicators. These dashboards can provide the data and analysis at 45- to 60-second updates; they also allow the building to be used as a learning tool for design and construction, operations and maintenance, and curriculum and instruction departments while using the same information in various ways (html, RSS, xml, Internet web widgets, etc.), as shown in Figure 14.

Concurrently with this metering and analysis, students began working with the Facilities Department, architects/engineers and teachers/designers, to develop and utilize building energy simulations from AutoCAD drawings to understand how the buildings can and should perform under various operating conditions, as shown in Figure 15.

## CONCLUSION

This project began as a "team" process with the Design and Construction, Operations and Maintenance, and K-12 Curriculum and Instruction Departments with the goal of working together to support the learning environment, maximize comfort conditions, and reduce energy use.

The curriculum aspect of this project has mushroomed into a major learning opportunity for the classroom. Now seniors in the pre-architecture and engineering class at Technology High School are required to submit a final project to design a structure in CAD that incorporates some type of energy conservation features using a simulation approach. This will demonstrate just how energy efficient their structures are. To date, two high school students were selected as energy interns because of their innovative approach to the program, as shown in Figure 16. They have researched energy efficient programs that would work with their projects. They also researched LEED components and features. Because of their enthusiasm and innovation, they are now working after school in the Facilities Department as interns, which will further deepen their knowledge. These students were instrumental in creating graphic pages for the districts mechanical systems and district wide direct digital control system. This is one way in which the project has provided students with a real-time, real-world application–designing and operating buildings with a new outlook and awareness of energy efficiency and energy conservation.

An additional benefit of using "open-source" facility management portal and Internet communication has been to support the science, math, engineering and technology curriculum. "Building as a Learning Tool" is bringing real-world data and experiences into the classroom and allowing students to take an active part in the day-to-day operation of facilities. There is a section within the Facility Management portal for students and teachers to add links and reports on the energy models and analysis work that they have completed.

To take action on this new information, the Facility Department utilizes the building work order, direct digital control monitoring and control points, and personnel- and/or equipment-initiated work orders to troubleshoot, correct and repair problems. Results of this work and lessons learned are shared via the district's Facility Management portal.

This technical presentation is a work-in-progress and will continue in various forms over the life cycle of the building. As noted in Figures 12 and 13, the energy bills are incomplete. In a large organization such as the Newark Public Schools, it will continue to be a challenge to verify accurate energy consumption. The unique approach of using an energy dashboard will help solve many of these problems and promoter the efficient management of resources.

When the "Building as a Learning Tool" project began, it was impossible to even begin to answer the basic questions about building energy use at the Belmont Runyon School posed at the start of this article. The implementation of this project has seen the development of important tools for exploring the answers to these questions.

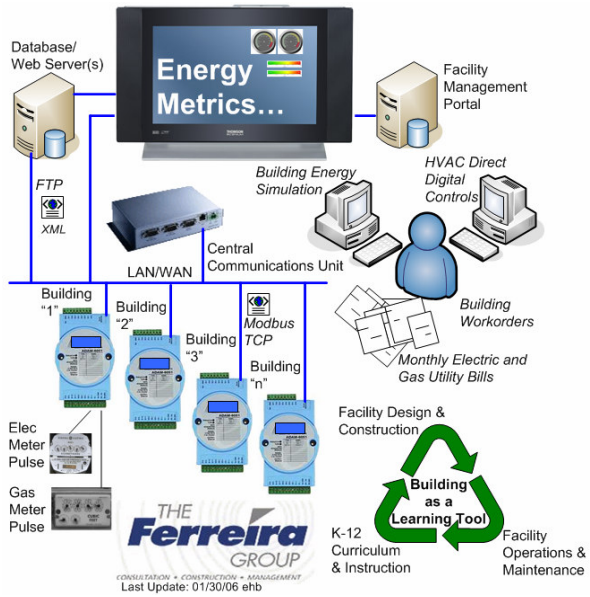

Figure 1 Project Graphic Overview

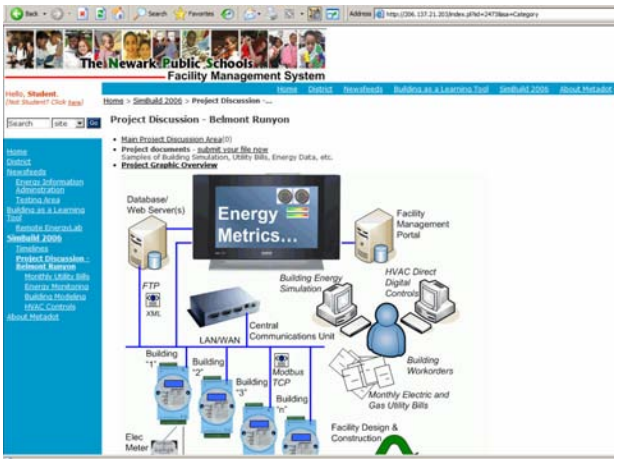

Figure 2 Facility Management Portal

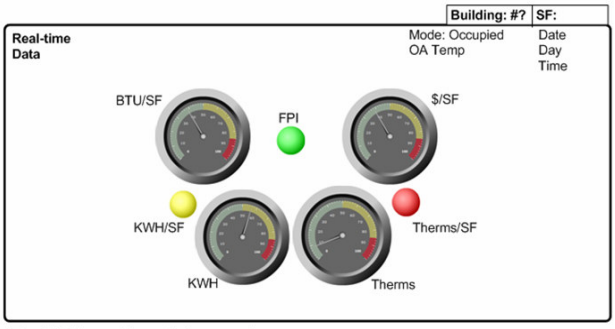

Figure 3 Sample Building Energy Dashboard

## ACKNOWLEDGMENT

We respectfully acknowledge and thank the following individuals for the assistance and support:

- Marion A. Bolden, State District Superintendent
- Jerry Bruno, Director School-to-Career & College Initiatives
- Wanda Wormley, Coordinator School-to-Career
- Oscar Rivera, CAD Teacher, Technology High School

## REFERENCES

See Newark Public Schools Facility Management portal. http://206.137.21.203/

## FIGURES AND TABLES

Figure 4 Distance Learning and Video Conference

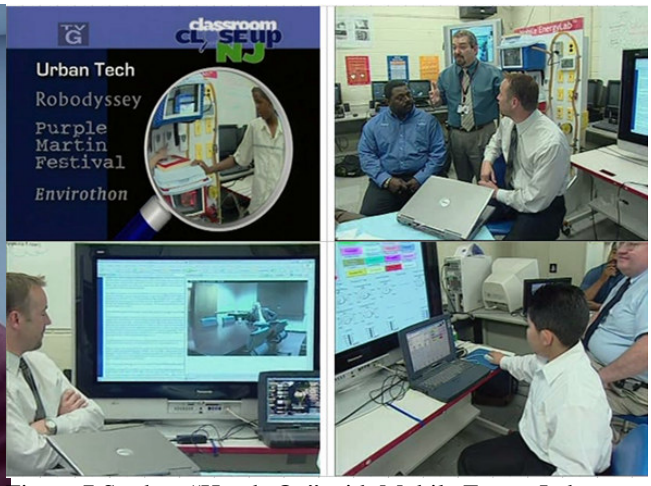


Figure 7 Student "Hands On" with Mobile EnergyLab

Figure 5 Student CAD Workstation


Figure 8 Student Field Trip to "Zero Energy" Building

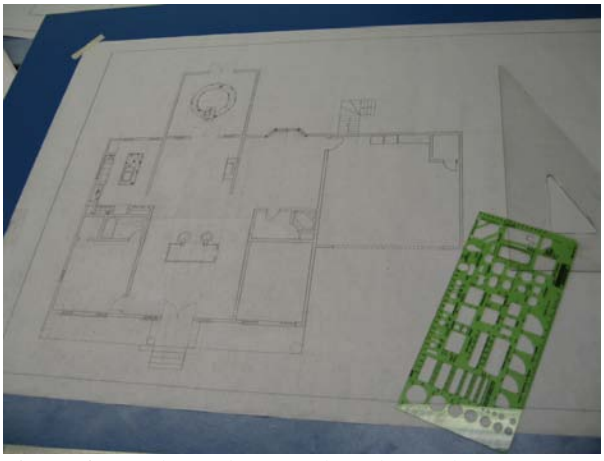

Figure 6 Sample Student "On board" Work

Figure 9 Network (LAN/WAN) Based Pulse Metering

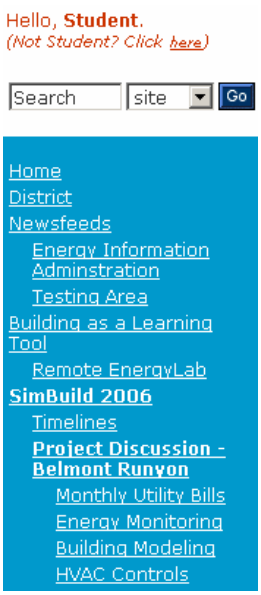


Figure 10 Sample Close-up of FM Portal, Student Access

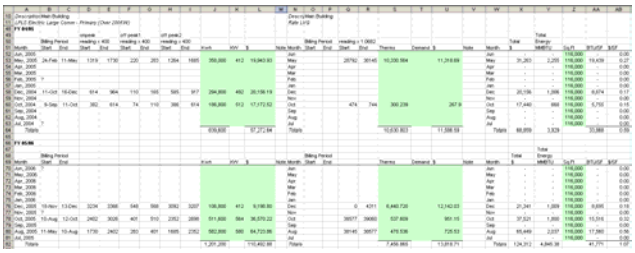

Figure 13 Monthly Utility Data, Electric, Natural Gas

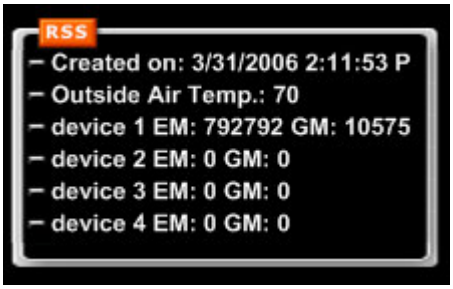


Figure 14 Yahoo Web widget RSS feed

Figure 11 Belmont Runyon School

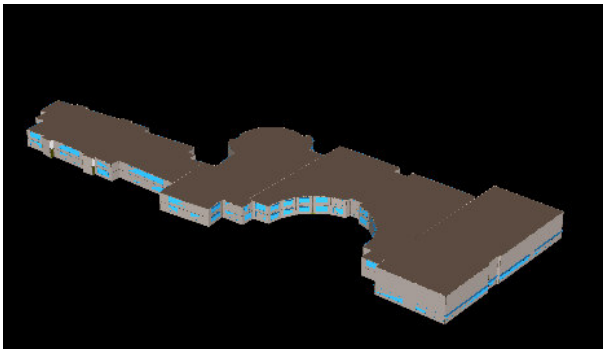

Figure 15 Building Energy Simulation Model

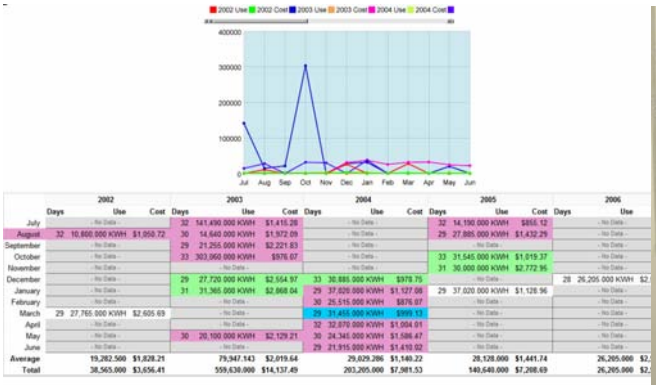

Figure 12 Online Utility Tracking (w/o data verification)

Figure 15 Tech High School Energy Interns