ASHRAE Building EQ Empowers Schools, Teaches Students

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The ASHRAE Building Energy Quotient (Building EQ) platform has been used on a variety of building types worldwide, including office, institutional facilities, colleges, universities and K–12 schools. This article explains how Building EQ was used as a collaborative tool between an ASHRAE chapter, its local student branch and the local school district to conduct Level 1 Energy Audits compliant with ASHRAE Standard 211-2018, *Standard for Commercial Building Energy Audits*, and to provide hands-on experience to engineering students. It created a model for other ASHRAE chapters to better engage their professional and student membership with their local communities.

Background

The ASHRAE Florida Institute of Technology (Florida Tech) Student Branch, working with the ASHRAE Space Coast Chapter, formed at the time, established a pilot program with Brevard Public Schools (BPS) for conducting energy audits at three K–12 schools using Building EQ (see "What are Building EQ and ASHRAE Level 1 Energy Audits?" sidebar on page 34). This pilot program was intended to be used as a first step toward completing energy audits for all of BPS' K–12 facilities. K–12 public schools in Brevard County, Fla., consume nearly 111 million kWh of electricity on an annual basis, costing just over $12 million. When comparing energy costs among Florida's 67 public school districts, BPS' energy expenditure is the eleventh largest.[1] Completion of energy audits for these schools would document which facilities had more opportunities to reduce the school district's energy footprint, an important first step in creating proposed projects for maintenance and capital expenditures by the school board and the school district's current facilities improvement surtax.

Building EQ was used to facilitate the audits and train university engineering students how to conduct ASHRAE Level 1 Energy Audits. Students also gained hands-on and on-site experience on the functions of each building's systems, including mechanical, electrical, plumbing and envelope systems. The goal was empowering the school district with information to

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reduce energy costs while providing a hands-on experience for engineering students.

The pilot program initiated the transition from using Energy Star® Portfolio Manager to using Building EQ to incorporate energy audits in the building energy performance assessment process. Energy Star® Portfolio Manager, a free benchmarking program provided by the U.S. Environmental Protection Agency,[2] was used by BPS to assess K–12 facility energy consumption district-wide and recognize schools with a higher percentile ranking compared to peer schools. Schools with higher energy consumption did not receive appropriate follow-up for EEM assessment, as would be done in an ASHRAE Level 1 Energy Audit, due to lack of personnel and attention placed on high-performing schools. Furthermore, Portfolio Manager data was inaccessible to BPS personnel during times of the U.S. federal shutdown and when the Energy Star® program was upgrading their websites,[3,4] times when access to the program's website was necessary for benchmark reporting in the district.

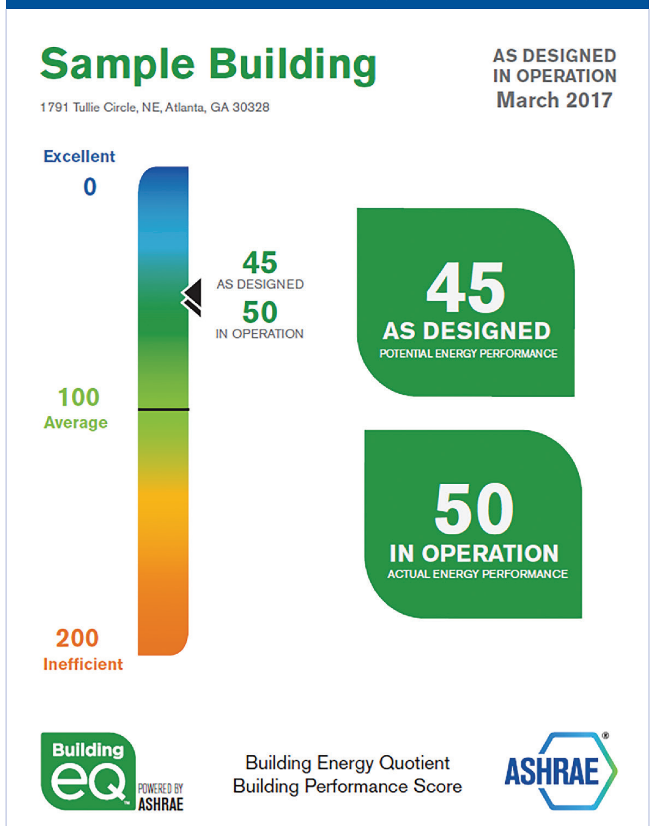
Although acknowledging that Energy Star® Portfolio Manager has more buildings reported on its website than the Building EQ Portal, BPS personnel noted that the ASHRAE Building EQ Portal did not encounter these recurring or extensive shutdowns due to attention placed on high-performing schools and lack of personnel.

The program benefitted the school district through actions brought to the school board; the ASHRAE Space Coast Chapter saw increased engagement by the membership with their local community; and the ASHRAE Florida Tech Student Branch introduced energy auditing training to their student membership to better prepare them for the workforce.[5]

The students who participated in this pilot program have all developed further interest in the areas of energy and buildings; some have already joined the workforce, and others have decided to pursue graduate study in this area. The students presented their findings through a technical seminar to the members of the ASHRAE Space Coast Chapter in November 2019 and at the ASHRAE 2020 Winter Conference in Orlando, Fla., where the branch advisor and the BPS Energy Conservation Manager presented their findings to seminar attendees (*Figure 1*).

FIGURE 1 ASHRAE Florida Tech Student Branch advisor (center) and student members at the ASHRAE 2020 Winter Conference after their seminar presentation.

FIGURE 2 Sample Building EQ Label with As Designed and In Operation ratings.[7]



Planning and Implementation

Five students, including two senior undergraduate and three graduate Florida Tech students majoring in mechanical engineering who are ASHRAE Florida Tech Student Branch members, signed up for the pilot program. Three BPS schools were identified and the audits were scheduled.

What are Building EQ and ASHRAE Level 1 Energy Audits?

ASHRAE Building EQ is an online web portal that compares a building's energy performance, whether As Designed or In Operation, with other buildings of its same type in the same climate zone and assists with the completion of an ASHRAE Standard 211-compliant Level 1 Energy Audit.[6] Building EQ provides both an operational rating (In Operation) and asset rating (As Designed), which meets the needs of the local school district for the pilot program.

Furthermore, Building EQ validates the licensure or credentials (i.e., U.S. Department of Energy Better Buildings certifications approved for energy auditing professionals for In Operation ratings and energy modeling professionals for As Designed ratings) in alignment with ASHRAE Standard 211 of professionals submitting projects for ratings.[6] This ensures integrity of the data collected and work completed. A Portal user who is licensed or credentialed with a non-ASHRAE certification would need to be validated for a nominal fee prior to submitting an In Operation project.

Upon project submission, the user may obtain the building's In Operation label with the Building EQ score free of charge (*Figure 2,* page 33) and can choose to purchase completed ASHRAE Standard 211 Normative Appendix Forms (i.e., audit spreadsheets) and a completed Standard 211-compliant Level 1 narrative report using information uploaded to the Building EQ Portal.[7]

The benchmarking of the In Operation rating is completed through a calculation of the building's energy use intensity (EUI) by the Portal as compared to a baseline median EUI to determine the Building EQ building energy performance score. The building's EUI is calculated using one year's worth of energy consumption information, or metered data, for the building. Alternatively, for the As Designed rating, a building's EUI may also be calculated using an energy model. The As Designed rating may be best suited for buildings with less than one year of operation or when looking at buildings with a different building use.

For both ratings, the methodology used to calculate the baseline median EUI depends on the building type. For building types used by Energy Star, the median EUI is calculated using Architecture 2030's Zero Tool,[8] which includes adjustments for climate zone and other variables. Remaining building types on the Building EQ Portal use the methodology from Appendix J in ASHRAE/IES Standard 100-2015, *Energy Efficiency in Existing Buildings*, which includes an adjustment by climate zone using multipliers from the Standard.[6,7,9]

In all cases, the calculation uses the 2003 Commercial Building Energy Consumption Survey (CBECS), published by the U.S. Energy Information Administration. The use of 2003 CBECS, rather than later versions of the survey, is intended to align the As Designed rating with ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, which uses the 2004 version of the standard as a fixed baseline. The resulting score is calculated as follows.[7]

$$\text{Building EQ Score} = \left(\frac{EUI_{metered}}{EUI_{baseline}}\right) 100$$

Typical scores are within a 0 to 200 range, with 0 representing net zero energy consumption by the facility, 100 representing an average building and 200 representing an inefficient building. Scores may be negative, in the case of buildings that produce more energy than consumed. On the other hand, scores may be above 200, should a building's EUI reflect inefficient building energy performance to result in such a score.

One aim of the Building EQ In Operation assessment is to assist with completing an ASHRAE Standard 211-compliant Level 1 Energy Audit. Level 1 Audits are intended to provide, at a minimum, a review of historical utility energy consumption and billing, on-site generation data, a site walk-through, identification of operations and maintenance issues, space function analysis of occupancy and energy consumption and identification of energy efficiency measures (EEMs).[10] The structure of the Portal walks a professional through the Level 1 Audit process per Standard 211. The inclusion of a survey of indoor environmental conditions provides information that is beyond Level 1 requirements.[7]

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The selected schools are all in Melbourne, Fla., and share one campus near Florida Tech. In the heart of Florida's Space Coast, Melbourne is in Climate Zone 2A, characterized by a humid subtropical climate and yearly average high and cold temperatures of 82°F (27.8°C) and 63°F (17.2°C).[11] School buildings have dedicated spaces for classrooms, offices, computer labs, library, cafeteria and kitchen. A central chiller plant with two 650 ton (2286 kW) water-cooled chillers serves all three schools. Since the chiller plant has its own dedicated meter, the share of each school from the chillers' energy consumption is roughly estimated based on occupancy, gross floor areas and limited measured data available.[12,13]

TABLE 1 Basic building information and bill data.

	SCHOOL I (ELEMENTARY)	SCHOOL II (ELEMENTARY)	SCHOOL III (MIDDLE)
Year Built	1987	2007	1987
Floor Area (ft^2)	96,778	121,348	199,214
Occupants	900 – 1,000	1,000 – 1,100	1,100 – 1,200
Operating Hours[a]	M – F: 7:30 a.m. – 3:30 p.m.	M – F: 7:30 a.m. – 3:30 p.m.	M – F: 8:30 a.m. – 4:30 p.m.
Energy Usage (kWh/yr)	996,704	1,073,024	1,944,752
Usage Rate ($/kWh)	0.0485	0.0482	0.0391
Demand Rate ($/kW)	9.203	9.298	11.451
EUI Site (kBtu/ft^2·yr)	35.14	30.15	33.3
EUI Source (kBtu/ft^2·yr)	110.34	94.7	104.6
Building EQ Performance Score[b]	71		

[a]The operating hours during the academic year indicated are from mid-August through May, with intermittent breaks in December and from June to mid-August.
[b]Since the performance score was based on the campus as a multiuse property, the score reflects all facilities on the campus, not the individual schools.

Since the schools and the chiller plant use a common meter, one multiuse property In Operation project was created on the Building EQ Portal for the campus. No Energy Star score was provided by BPS personnel as a basis of comparison, since energy consumption of the schools and chiller on the campus were measured off one meter, as opposed to each school and the chiller plant having a meter.

The information regarding the share of each building from the chiller plant energy consumption was provided by the BPS staff, and it is only used to estimate the individual energy consumption for each school. However, the Building EQ generated score was obtained for the overall campus of the three buildings to avoid any error associated with this estimation.

Prior to the audit, the student branch advisor discussed the audit procedure with the students and worked with them to prepare a comprehensive questionnaire for the site visits. Building EQ was used as an effective tool in preparing the questionnaire and training the students before the audits. The questionnaire served as a reference for the team during the audit to collect detailed information, including general building information (year built, gross floor area, number of floors, conditioned area, etc.), schedule of operation, energy sources and meters, lighting (light count, types of lights, any sensor, etc.), HVAC system (types of equipment and control, setpoints, insulation condition, etc.), hot water (type of system, insulation condition, etc.) and other energy end users (computers, projectors, refrigerators, other plug loads, etc.)

The bill data were acquired from the utility company, and a detailed bill analysis was performed to provide a clear picture regarding the current energy consumption of the schools and the associated rate schedules. The bill data as well as basic building information were entered in the Building EQ Portal, and the energy use intensity (EUI) scores were calculated by the Portal. This provided a picture regarding the energy performance of the building relative to its own building type in the same climate zone, Zone 2A in this case. The summary of the basic building's information, bill analysis and Building EQ Building Energy Performance Score are shown in *Table 1*.

During the audit (*Figure 3*), the audit team collected data related to energy consumption including light count and equipment name plate information as well as indoor environmental quality (IEQ) measures such as temperature, relative humidity and carbon dioxide concentration. The team also collected or confirmed facility and occupant data, including schedules of operation, facility interior area and number of occupants. The students used Building EQ to record data associated with each audit and were able to work together on data entry and analysis, thanks to the collaborative nature of the web-based Building EQ Portal. Building EQ was also used as a reference to teach students about the potential best practices and EEMs in commercial buildings, which are mostly based on information from ASHRAE Standard 100-2015 appendices.

Following the audits, the students worked closely with BPS personnel and the student branch advisor to generate detailed reports for each school. The Florida Tech team identified EEMs under three different categories: lighting systems, on-site power generation using rooftop solar photovoltaic (PV) panels, and HVAC. For each EEM, the energy savings, demand savings with the associated costs savings, implementation cost and the simple payback period were determined.

The evaluation of EEMs were performed to provide further experience for the students (beyond a typical Level 1 audit). This is done through estimating the energy consumption before and after implementation of each EEM. The calculation process is elaborated in another paper,[12] and briefly summarized in the next section. Since the purpose of this article is to document the process and success story of the collaboration between the ASHRAE Student Branch, the ASHRAE Space Coast Chapter, the local school district and the Building EQ Committee, the detailed calculations are not included.

A list of currently in-use best practices was also prepared to recognize the energy-efficient practices that were already implemented in the school buildings. These are summarized in the next section.

Results and Discussion

The Building EQ Performance Score of 71 for the campus reflected that three schools and the chiller plant servicing the campus performed above average. This score signifies that the campus of facilities cumulatively performed better than similar campuses containing elementary/middle school buildings with similar amounts of interior floor areas in Climate Zone 2A. However, submetering for each school and the chiller plant would provide more granular electric consumption data, better assess energy performance for each school, and direct specific EEMs to certain schools rather than apply EEMs campus-wide, regardless of benefit of the EEM to the school.

FIGURE 3 Students at school facilities assisted with energy audits.

The best practices that were already implemented in the school campuses to reduce energy cost are summarized as follows:[12,13]

- Setpoint temperature of 76°F (24.4°C) used for all classrooms and office areas;

- Chillers equipped with variable frequency drive (VFD) control;
- Chilled water pipes properly insulated;
- Chillers not operating during the unoccupied hours;
- Tinted glass used for the windows; and
- Light-color roofs used for two of the schools, reducing cooling load.

The EEMs identified and a brief description on how they are evaluated are listed below:

EEM 1—Lighting Systems: Replace Fluorescent (T8-32 W) lights with LEDs (12 W). The energy consumption by the existing lights is estimated using the light count, the rated power of each fixture, the ballast factor and operating hours. The energy consumption by the equal number of LED replacements is also evaluated, and the difference between the energy consumption before and after replacing lights is calculated as the energy savings.

EEM 2—Lighting Systems: Install Occupancy Sensors in Spaces with Intermittent Use (Classrooms, Offices, Hallways, Etc.). Assuming EEM 1 is already implemented, the savings associated with installing occupancy sensors is evaluated considering a conservative 20% reduction in operating times for the lights.

EEM 3—Lighting Systems: Replace Security Lights (Incandescent 60 W) With LEDs (9.5 W) and Install Photosensors. The energy savings is the difference between the incandescent lights that are operating continuously (i.e., 24 hours per day, 7 days per week) and LEDs that operate for reduced hours (4:00 p.m. to 8:00 a.m.).

EEM 4—Onsite Power Generation: Install Rooftop PV Panels to Cover Approximately 50% of Annual Energy Load of the Buildings, Excluding the Chillers' Energy Use. It is assumed that approximately 50% of the energy load by each school building is going to be covered by rooftop PVs, and the system is sized using System Advisor Model (SAM) by defining the location.

System Advisor Model (SAM) is a software model developed by the National Renewable Energy Laboratory (NREL) that conducts performance and economic analyses on renewable energy projects.[2] The PV arrays are sized to cover approximately 50% of the energy load of each school building (150 kW dc, 160 kW dc, and 290 kW dc for School I, School II, and School III, respectively). The monthly energy generation and corresponding cost savings are calculated using SAM.

TABLE 2 Summary of EEMs' energy savings, total cost savings and estimated payback periods.

	EEM	ENERGY SAVINGS (KWH/YR)	TOTAL COST SAVINGS ($/YR)	EST. PAYBACK PERIOD (YEARS)
School I	EEM 1	76,214	8,150	1.8
	EEM 2	13,874	722	4.2
	EEM 3	23,090	1,497	0.5
	EEM 4	294,870	18,746	13.3
	Total	408,048	29,115	
School II	EEM 1	161,381	17,306	1.8
	EEM 2	23,502	1,216	3.7
	EEM 3	34,635	2,245	0.2
	EEM 4	314,528	20,167	13.1
	Total	534,046	40,934	
School III	EEM 1	145,463	17,052	1.7
	EEM 2	21,184	999	5.7
	EEM 3	48,478	3,201	0.2
	EEM 4	570,082	36,344	13.2
	Total	785,207	57,596	
Chiller Plant	EEM 5	–	94,316	6.6
	Overall	1,727,301	221,961	8.4

EEM 5—HVAC Systems: Install Thermal Energy Storage (i.e., 47 Ice Storage Tanks) to Shift Electrical Demand Loads to Off-Peak Hours. The local utility company offers an attractive $600 rebate per kW shifted demand for thermal energy storage. It was estimated that for installation of 47 ice storage tanks that are needed to shift the 12,672 kBtu/h (3,714 kW) chiller demand, the school district would qualify for nearly $406,000 in rebates, significantly helping with the EEM's payback period.

The assessment of thermal energy storage to be installed was evaluated using the overall energy consumption of the chiller plant and not the energy consumption by the individual schools.

These EEMs were analyzed in detail, with summarized findings shown in *Table 2*.

A 58% reduction in the schools' electricity cost can be realized by implementing the five EEMs listed in *Table 2*, resulting in an overall simple payback period of 8.4 years. The high energy and cost savings potential from these EEMs are very encouraging. Even though the payback period for some of the EEMs does not look too attractive, given the long life span of the proposed systems, the measures are still considered very viable.

The process that was developed by this pilot program to conduct energy audits for K–12 schools is replicable and can be used by other ASHRAE student branches for their local K–12 schools as an excellent educational experience for engineering students, added value for future engineers and their employers and for the local school district and community.

Conclusions

Through a collaborative effort between the ASHRAE Florida Tech Student Branch, BPS, the ASHRAE Space Coast Chapter and the Building EQ Committee, a pilot program was established to perform energy audits for K–12 school buildings in Melbourne, Fla. The purpose of this activity was to empower the school district with information while providing hands-on experiential training for engineering students. ASHRAE Building EQ was an important component of this effort, helping with the documentation of the audits and with teaching students about the audit process. The pilot program was successfully completed with participation of five students and the inclusion of three schools. The major findings of the project are as follows:

Five EEMs were identified pertaining to lighting systems, on-site power generation and HVAC systems. It was found that implementation of all five EEMs would result in a total of 58% reduction in the schools' energy costs.

While the lighting EEMs were found to be the most attractive options for quick payback, the installation of the ice storage tanks were also very attractive due to the generous rebate program offered by the local utility company.

On-site power generation through rooftop PVs had a relatively long payback period. This EEM's cost-effectiveness would be greater if implemented along with other EEMs. Along with the long life span of solar panels, the return would be realized with the added value brought through energy savings, carbon footprint reduction and the opportunity for green energy education for elementary and middle school students.

ASHRAE Building EQ was used as a tool to facilitate the audits and train the students. The easy to use and accessible Building EQ Web Portal with multiuser functionality on the project fosters collaborative work. The comprehensive set of inputs along with a professional's experience can be effectively used to prepare site visit questionnaires. The energy audit report feature also provides an educational opportunity for students to see the process of an ASHRAE Standard 211-compliant Level 1 Energy Audit and how their work meets audit requirements. The Portal provides thorough guidance that is comprehensive and easy to use.

Acknowledgments

The Building EQ Pilot Program would not have been possible without the efforts and dedication of ASHRAE Florida Tech Student Branch members Ganesh Doiphode, Obinna Uyanna, Tejas Thakur, Bhaskar Aggarwal and Mariana Migliori. The support from the BPS Energy and Resource Conservation Department staff, Joseph Montemurno and Charles Mcmahon, is also greatly appreciated.

References

1. Florida Department of Education. 2019. "Florida School District Annual Energy Cost Information." Florida Department of Education. https://tinyurl.com/kw88p3dp

2. U.S. EPA. 2016. "Portfolio Manager." U.S. Environmental Protection Agency. https://tinyurl.com/f533nupn

3. Quakenbush, J. 2013. "Energy Star Portfolio Manager shutdown extended." *The North Bay Business Journal* July 2. https://tinyurl.com/5acyrtz6

4. BOMA Canada. 2018. "Breaking News: Potential Shutdown of Energy Star Portfolio Manager." BOMA Canada. https://tinyurl.com/2p858s8c

5. Lindsay, B. 2020. "First Steps: Building EQ Pilot Program for Brevard Public Schools." 2020 ASHRAE Orlando Winter Conference, Seminar Presentation.

6. ASHRAE. 2021. "Building EQ." ASHRAE. https://tinyurl.com/5yduruv4

7. ASHRAE. 2019. "ASHRAE's Building EQ: Be an Energy Genius." ASHRAE. https://tinyurl.com/4j4cveck

8. Architecture 2030. 2021. "About the Zero Tool." ZeroTool.org. https://tinyurl.com/2p8kta4c

9. Sharp, T.R. 2014. "Derivation of Building Energy Use Intensity Targets for ASHRAE Standard 100." Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the U.S. Department of Energy. Document ORNL/TM-2014/215.

10. ANSI/ASHRAE/ACCA Standard 211-2018, *Standard for Commercial Building Energy Audits*.

11. U.S. Climate Data. 2019. "Climate Melbourne—Florida." U.S. Climate Data. https://tinyurl.com/4bdu44sw

12. Doiphode, G., H. Najafi, M. Migliori. 2021. "Energy efficiency improvement in K–12 schools: a case study in Florida." *Journal of Engineering for Sustainable Buildings and Cities* 2(1):011001. https://doi.org/10.1115/1.4048894

13. Doiphode, G., H. Najafi, M. Migliori. 2020. "Energy Efficiency in K–12 Schools: A Case Study in Florida." ASME Energy Sustainability Conference, Paper No. ES2020-1632. ■