High Performance Buildings Using Whole Building Integrated Design Approach

Mohamed Abaza, LEED AP BD+C,HBDP

ABSTRACT

High Performance Building Programs

High Performance Building (HPB) programs have become a model for greater resource and energy efficient practices for selected renovations and new construction projects. The goal of the HPB program is to produce a permanent improvement in standard design practices among building designers and owners that results in higher efficiency and lower utility costs while incorporating many of the sustainable building practices being recognized by the US Green Building Council.

ENERGY MODELING AND LIFE CYCLE COST ANALYSIS

Energy conservation is central to long-term economic and ecological sustainability. Energy efficiency is not only directly tied to occupancy and program use but is also specific to the design of the building. Design teams can use energy modeling to determine the estimated energy consumption of a facility before the first brick is placed. Energy modeling is the common term used for an integrated, whole building, hourly energy simulation. It can be simply explained as a tool used to predict annual energy consumption in a building. The model is developed using computer software programs such as Trane Trace or Visual DOE and input parameters such as building design, orientation, climate zone, utility rates, and heating and cooling loads. While the engineer of record (EOR) will perform energy analysis to determine the proper selection of equipment to meet building loads, this whole building energy model is different; rather than selecting equipment, this model will demonstrate the performance of equipment in the operation of the facility. Creating the model and then analyzing the outputs requires a specialized skill set, which includes working closely with the design and operations team.

The first model to be run is always that of the base case building—What would the consumption be if the building were designed only to code? Next, the building is modeled as designed, with individual energy conservation measures (ECMs) entered and their effect on consumption analyzed. These ECMs are essentially upgrades to the systems and can include any potential modification to design, including envelope, insulation, equipment, window, systems, or other suggestions. Results of each ECM impact are presented in the energy modeling reports. Based on the value engineering results, the most cost effective ECMs are selected, and the whole building design is modeled incorporating all of the chosen ECMs. This can be very helpful in understanding the effect on energy consumption and costs that can result when removing ECMs during the value engineering process.

The energy model is built in early design and updated throughout the process. Reports are submitted, beginning in the schematic design phase, with the most cost effective impact coming no later than design development. The energy model is also updated as required and re-submitted at the construction document phase. It is important to perform the modeling as early as possible so that any ECMs can be value engineered early.

The maximum number of points under LEED Energy and Atmosphere Credit 1 can only be earned by performing an energy model, which will demonstrate the percentage improvement in the proposed building performance rating compared to the baseline performance rating per ASHRAE 90.1 requirements. Modeling can also be used to determine on-site renewable energy and green power as a percentage of the base case energy consumption. Energy models are also required for certain government, utility, or other energy efficiency grants and incentives.

Life cycle cost analysis (LCCA) is a practical method and a useful guideline for evaluating the economic performance of building service systems. By using LCCA, the most cost effective design decision can be made, determining which has the lowest life cycle cost during the project study period among the various design alternatives and ECMs and maximizing the return on investment.

Life cycle cost analysis balances long-term operations and maintenance with the first cost budgetary concerns of the project. Several factors are considered when calculating LCC, which requires information from several key team members. Estimators and contractors can provide the first cost of the equipment, including materials, installation, delivery, etc. The manufacturer can provide maintenance and utility consumption requirements, which can then be applied to local rates and tariffs; however, the latter is best obtained by performing a whole building energy model. Finally, replacement costs and overhaul information is also factored in to understand the full financial implications of a given system. Each building system can be analyzed in this manner to calculate the cost of ownership.

The hourly-based LCC results indicate that as efficiency increases, the lifetime operating cost has greater impact on the LCC than does the total installed cost. In other words, the increase in total installed cost that occurs when equipment efficiency is increased is offset by the decrease in lifetime operating costs.

ENERGY EFFICIENCY OF LEED

Here is where a basic problem lies: to date no one has been able to put a dollar value on the cost of environmental impact, or environmental impact avoidance. Yes, we all know that LEED takes into account environmental impact; however, it does not spell out the exact dollar value of the impact, and no one can. The only measurable impact is energy, and that is why the emphasis has always been on energy.

In fact, when the originators first began LEED they championed themselves on being able to conserve energy through their system. Maybe they should have been more careful with the way they marketed the program. The truth is, if they had not marketed it that way, there would have been very little buy-in. Owners are more concerned about energy cost savings than they are about the cost of environmental impact avoidance. The fact is, the cost savings associated with environmental impact avoidance is higher than the energy cost savings. In an effort to maximize LEED points, energy modelers have been pushing the envelope and lowering the energy use intensity (EUI), sometimes using unrealistic occupancy and equipment schedules that do not accurately depict actual schedules. Energy modeling is only a prediction and an engineering tool, not the solution; the modeling results are subject to who is using the software. Ultimately the greatest energy savings will be reflected through the occupants/tenants, and the correct commissioning and ongoing measurement and verification after occupancy.

The final whole building design model should take into account the building's performance in its entirety. That is why the modeling process should be integrated right from the design charette all the way to and after commissioning. The process should be an iterative process. This process will ensure that the whole building design will take into account the building's performance in its entirety, once systems are installed and operational. Increased energy consumption during the initial months of occupancy due to incompletely installed or commissioned systems can thus be avoided.

Energy efficiency has to be monitored, mainly through sub-metering or utilizing smarter building systems, while information technology (IT) and building automation systems (BAS) are all merged onto one internet protocol (IP) platform. In the future this monitoring will be done wirelessly by using quantum technology, which is currently being researched by the Defense Advanced Research Projects Agency (DARPA). Continuous commissioning and monitoring are essential in maintaining energy performance.

Contrary to popular belief, incremental costs associated with construction of LEED buildings is only marginally more than "traditional" costs of construction.

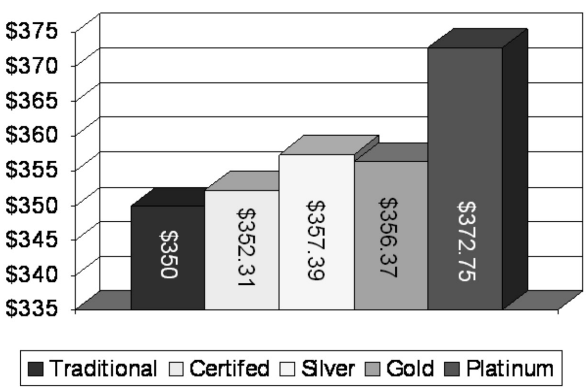


Figure 1. LEED Cost by level vs. $350/sf[$32.5/m^2] traditional construction

PLANNING AND ACHIEVING HIGH PERFORMANCE BUILDINGS (HPB)

The HPB program includes several ways to access available incentives that are based upon the complexity of the project and the schedule. Pre-qualified equipment, custom measured (system-based), and whole building incentives are offered. These three opportunities allow flexibility for the HPB program to help as many building owners as possible to participate. A building must sufficiently reduce the electric demand and electricity use (with emphasis on demand reduction) to satisfy the HPB program requirements.

Design-team communication is equally as important to successful building performance as efficient mechanical systems are.

The 2030 Challenge proposed by ASHRAE/IESNA and USGBC 189, *Standard for the design of High Performance Green Buildings except Low-Rise Residential Buildings*, has made high performance buildings increasingly popular. Creating buildings that respond to increased demands for energy efficiency and carbon accounting while balancing efficiency goals with economic constraints is extremely difficult to achieve.

The meter for high performance buildings is KBtu/SF/YR[kWh/m^2/YR], which is the equivalent of automobile mpg; however, high performance buildings behave in a manner opposite to that of high performance vehicles. The benchmark to which a high performance building is compared is the Commercial Buildings Energy Consumption Survey, or the ASHRAE 90.1 energy standards. To be sustainable, high performance buildings must be economical, taking into account first costs, life cycle costs, and return on investments. Economy can be achieved on a system level and then on a component level. The system level, for example, could be building orientation, and the component level could be variable frequency drives on pumps and air handling units. High performance buildings will use less material more effectively, are more durable, and require less maintenance.

Requirements for High Performance Design

- Entire design team to be part of design process from the start.
- Building to meet owners project requirements (OPR).
- Value Engineering (VE) changes are tracked back to the basis of design (BOD) and OPR to ensure that energy efficiency measures

were not eliminated.

- Whole building is approached as one system.
- Use of energy modeling to predict energy consumption.
- Economic decisions must include life-cycle costs.
- Energy, resources, and materials to be used efficiently.
- Use of durable materials that require less maintenance and are recyclable.
- Incorporate QA process of commissioning into the design and delivery process.

Requirements for Efficient HVAC Design

- Examine heat flow though the building via computer economic analysis to ensure reduction in HVAC equipment size.
- Capture natural-energy flows, such as passive solar heating, daylighting, natural ventilation, and occupant-generated heat.
- Reduce internal loads by implementing daylighting and using Energy Star-labeled equipment.
- Divide the building into thermal zones, resulting in higher system controllability and greater occupant satisfaction.
- Use multiple-zone control within larger units.
- Reduce system losses in ducts and piping.
- Use low-pressure duct work.
- Employ premium efficiency motors.
- Use variable-load fan systems and consider part-load performance in equipment selection, since the peak load is only needed 1% of the time.
- Employ occupancy-based, time-of-use, and demand-based controls.
- Use energy recovery for ventilation air.
- Curtail electric loads during peak demand period (could be achieved by using ice storage systems).
- Use only high efficiency mechanical systems.
- Establish an operations and maintenance manual.
- Make provisions for proper performance monitoring and verification.

CASE STUDY

We are currently serving as the program manager for the City of New Haven Public Schools construction program, which includes construction or renovation of 47 facilities totaling over 3.9 million square feet [362,310 m^2]. The $1.47 billion program now stands as a national model, for its massive scope, innovative financing, high degree of community support, construction standards, and outstanding design.

The city needed to update its aging schools while trying to reduce energy costs, which have been rising at a rate of nearly 8% per year since 1988. We helped the city identify high performance goals and met with the entire project team—city officials, architects, engineers, consultants, construction managers, maintenance personnel, and end users—to go through them. The city's high performance goals were to:

- Provide immediate and ongoing cost avoidance to the school system.
- Ensure that new buildings are designed and constructed to meet high performance efficiency and green building guidelines.
- Improve thermal comfort of building spaces and increase system reliability.
- Commit specialized technical resources to assist with technical challenges related to energy.
- Create an opportunity for students and staff to participate in the program and learn about energy efficiency.

We developed standards concerning materials, design, construction, and energy efficiency. All of the schools are now designed to high performance standards and meet Energy Star efficiency levels. Within the first year of the high performance initiative, New Haven achieved $1.1 million in cost avoidance without capital investment. To date, over a 5-year period, the city has saved over $10 million from a reduction of over 65% in average overall building operating efficiency.

At the core of the program is our *High Performance Program*, a comprehensive, value added, integrated design process. Early in schematic design, the entire project team, including design professionals, consultants, our program management staff, construction managers, commissioning agents, operations & maintenance personnel, and other stakeholders met for the first of four meetings to establish goals, timelines, and responsibilities relating to energy conservation and sustainable design, construction, and operation.

Using our High Performance Plan as a road map to being green, the team focuses specifically on the energy-consuming systems within the building. Throughout the process, these decisions will be vetted though comprehensive and periodic whole building energy modeling simulations to determine what effect that design and equipment decisions have on the expected energy consumption, compared to code as well as to initial design.

By using the building's ENERGY STAR rating and energy use intensity (the amount of total energy per square foot used in a year, reported in kBtu/sf/yr [kWh/m^2/yr]) as a benchmark, the design can be compared fairly with peer facilities. As ENERGY STAR partners, we can also submit projects for the Designed to Earn the ENERGY STAR Award.

The High Performance Program also incorporates the discussion of LEED, with each of the rating systems credits included as line items in the overall plan, but it also guides project teams to think beyond the credits, sparking discussion in areas such as maintainability of systems, connections to the community, and specific program requirements.

By working with the design team and engineer of record, we brought the lessons learned from projects around the country and past experiences of the NHSCP to generate truly amazing results. Since beginning the program, designs have cut expected energy use in half, and the district as a whole has gone from an EUI of 234 kBtu/sf/yr[738 kWh/m^2/yr] to under 80 kBtu/sf/yr[252 kWh/m^2/yr].

Unique to the New Haven Program is a culture of continuous monitoring and improvement. Each building has been outfitted with sophisticated controls and monitoring systems to allow for a centralized view of performance at any given time. This data is being benchmarked, collected, and analyzed by both the maintenance and the school construction departments to maximize current and future investments in the program.

The Mayor's Energy Task Force for the City of New Haven, together with our program management, has advanced a significant high performance schools (HPS) initiative that may be among the first such comprehensive facility construction programs nationally. This group promulgated design guidelines, energy targets, and other performance requirements in 2003, and it is currently implementing a dozen projects by working closely with their design teams. A key component of implementation involves the use of computerized energy modeling in evaluating energy efficiency improvements and alternatives. Goals were set for the program that included Energy Star guidelines and exceeding ASHRAE 90.1 2004 (state energy code) by 30%.

Findings from Study

- Square footage of schools modeled: 985,400
- Square meters of schools modeled: 91,544

(*11 of 14 Schools indicated in square footage*)

- Potential of **30-40% Energy Costs Avoided**
- Avoided annual energy costs:
  Over $700,000
- 20 year lifetime savings over **$20,500,000**

Example Energy Efficiency Measures Implemented

- Insulated Building Envelope beyond Code
- High Performance Heating & Cooling Systems
- Demand Control Ventilation
- Optimized Lighting & Daylight Dimming
- Optimized Domestic Hot Water Heating
- Solar Power
- Thermal Storage

General Findings

Overall, energy modeling has contributed significant value to the design process in helping teams understand the rationale behind envelope, system improvements, and economics to incorporate numerous improvements.

Many of new building/major addition design teams were able to deliver designs offering potential energy cost avoidance of 30% above current code (ASHRAE 90.1, 2004) when high performance requirements were set towards the beginning of design.

All architectural design teams continue to be responsive to optimizing envelope features such as insulation and glazing.

Meeting the requirements to attain the *Energy Star Rating* as set in the design guidelines requires both aggressive design *and* operating strategies. The designs and energy modeling efforts are starting to indicate that Energy Star is achievable. Figure 2 indicates a trend that shows designs moving towards potential reduction in kBtu/SF[kWh/m^2] and the resulting ability to meet the Energy Star Requirements.

Reducing fan operating hours can reduce yearly utility bills further. These operating strategies, added to the energy modeling and design process, are already being implemented in the school district.

Implementing high performance design in the New Haven Schools reduced annual carbon dioxide emissions by an estimated

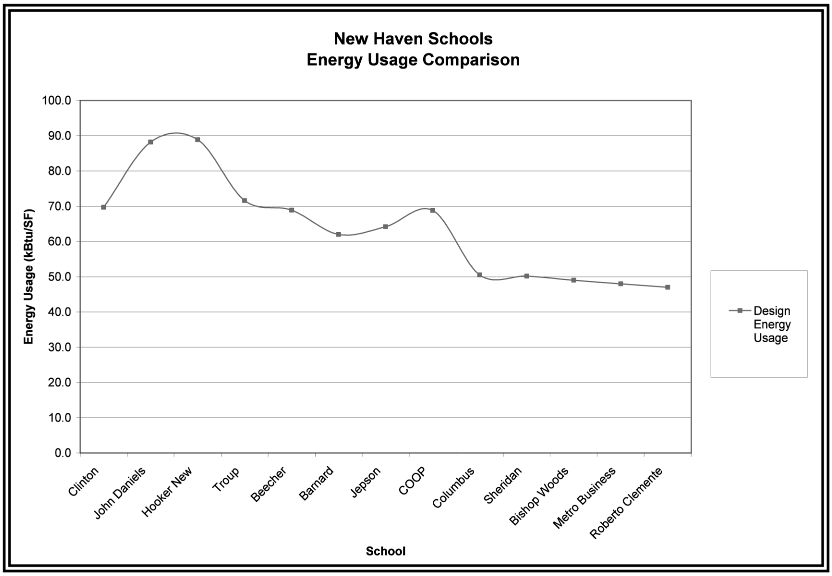


Figure 2. Design energy usage with respect to Energy Star rating

27%. For the schools modeled, it is estimated that over 5,750,000 pounds [2,608,200 kg] of carbon dioxide emissions have been avoided.

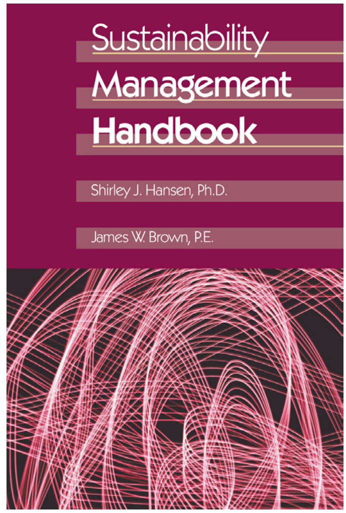
As can be seen in Table 1, a large improvement in energy usage has been seen between the previously designed buildings that had energy models performed and the later ones.

The Barnard School successfully incorporated strategies of massing, geometry, and orientation while at the same time responding to the urban design requirements of the site. Its desire to create a sheltered exterior space in the courtyard with ample south exposure led to its "U" configuration, admitting plentiful daylight.

	Initial Schools	Present Schools	Savings
Energy Used (kBtu/SF/yr)[kWh/m^2/yr]	74[233]	60[189]	20%
Energy Saved (kBtu/SF/yr) [kWh/m^2/yr]	29[91]	43[136]	47%
Energy Saved (%)	28%	42%	47%

Table 1. Energy use intensity comparison between earlier designed and current designed schools

SUSTAINABILITY MANAGEMENT HANDBOOK



Shirley J. Hansen, Ph.D., and James W. Brown, P.E.

Managing sustainability is THE challenge of our time. It's not just a technical issue and not just a green issue. It is a management issue. A strong sustainability program requires commitment, which in turn demands effective leadership. Such leadership must draw on a solid knowledge base, the ability to manage resources wisely, identify sustainability opportunities, make difficult choices, and accept the challenge to lead, influence and persuade colleagues. This book attempts to cut through the ever-present hyperbole to offer practical steps which can be taken now to protect the world around us. Rich in case studies, it addresses a range of critical stewardship issues. Growing out of a keen desire to protect the earth, the text is designed to help management transform important information and critical leadership skills into enhancing socially responsible operations. Authors Hansen and Brown have also included contributions from several additional leading experts in the field.

ISBN: 0-88173-644-9
6 x 9, Illus., 230 pp., Illus., Hardcover
$135

ORDER CODE: 0648

CONTENTS

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Sustainability Management Handbook	**0648**	**$135.00**	
			Applicable Discount	
			Georgia Residents add 6% Sales Tax	
			Shipping Fees	**10.00**
			TOTAL	

② Indicate shipping address: **CODE: Journal 2011**

NAME (Please print) ____________ BUSINESS PHONE ____________

SIGNATURE (Required to process order) ____________ EMAIL ADDRESS ____________

COMPANY ____________

STREET ADDRESS ONLY (No P.O. Box) ____________

CITY, STATE, ZIP ____________

MEMBER DISCOUNTS
A 15% discount is allowed to AEE members.
☐ **AEE Member (Member No.____________________)**

③ Select method of payment:
☐ **CHECK ENCLOSED**
☐ **CHARGE TO MY CREDIT CARD**
☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO. ____________

Expiration date ____________ *Signature* ____________

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

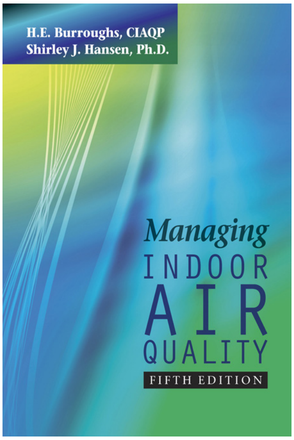
INTERNET ORDERING
www.aeecenter.org

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

MANAGING INDOOR AIR QUALITY, 5th Edition



H.E. Burroughs, C.I.A.Q.P., and Shirley J. Hansen, Ph.D.

This newly revised and updated practical desk reference is structured to serve as a guide and information resource—both on treating existing indoor air problems effectively, and on preventing costly IAQ problems from occurring in the first place. Finding solutions to indoor air quality problems is often a complex, multi-disciplined endeavor. A single-discipline approach from the environmental engineer, the industrial hygienist, or the medical doctor, unfortunately tends to narrow both the control and the treatment options. This book cuts across these professions to offer those concerned with the total facility, a broader, more comprehensive approach to managing indoor air quality and mitigating indoor air quality problems. Topics covered also include updated ASHRAE standards and information, expanded discussion of greening and sustainability, building security and mold-related issues, current diagnostics and remediation practices, and the latest information on filtering.

ISBN: 0-88173-661-9

6 x 9, 360 pp., Illus.
Hardcover, $000

ORDER CODE: 0654

CONTENTS

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Carbon Reduction: Policies, Strategies and Technologies	**0654**	**$125.00**	

② Indicate shipping address: **CODE: Journal 2010**

NAME (Please print) BUSINESS PHONE

SIGNATURE (Required to process order) EMAIL ADDRESS

COMPANY

STREET ADDRESS ONLY (No P.O. Box)

CITY, STATE, ZIP

Applicable Discount	
Georgia Residents add 6% Sales Tax	
Shipping Fees	**10.00**
TOTAL	

MEMBER DISCOUNTS
A 15% discount is allowed to AEE members.
☐ **AEE Member (Member No.____________________)**

③ Select method of payment:
☐ **CHECK ENCLOSED**
☐ **CHARGE TO MY CREDIT CARD**
☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO.

Expiration date *Signature*

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

INTERNET ORDERING
www.aeecenter.org

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

The daylighting emphasis here was designed in response to studies that show discernable performance improvements in students in day lit environments. Daylighting may require some tradeoffs. As a result, more aggressive ECMs were required to achieve desired energy targets. The result however, demonstrated an "r" high performer—appropriate for an "environmental magnet school" with higher quality lighting and with greater connection to the outdoors through views to a courtyard and vegetation.

New York City-based Roberta Washington Architects, in collaboration with David Thompson Architects and Dewberry Goodkind Engineers, designed the building to potentially achieve US Green Building Council LEED silver status. The intended goal is to achieve 6 points or a 40% improvement in energy performance over a base case as defined in ASHRAE 90.1, 2004. Barnard School incorporated solar power, gaining another 2 LEED points for renewable power, improving the overall energy performance.

BARNARD ENVIRONMENTAL MAGNET SCHOOL

U.S. GREEN BUILDING COUNCIL

LEED-NC 2.1 GOLD

40% More Energy Efficient
$58,174 in Annual Energy Savings
228,600 gallons[865,251liters] of Water Saved (33%)

3-D Model of the Barnard Environmental Magnet School

Roof Mounted Solar Panels on the Barnard Environmental Magnet School

LEED FACTS
Barnard Environmental Magnet School
New Haven, CT

LEED for New Construction
Certification Awarded TBD

Gold *(39-51 Points)*	***43***
Sustainable Sites	***6/14***
Water Efficiency	***4/5***
Energy & Atmosphere	***11/17***
Materials & Resources	***7/13***
Indoor Environmental Quality	***13/15***
Innovation & Design	***2/5***

Figure 3. LEED scorecard

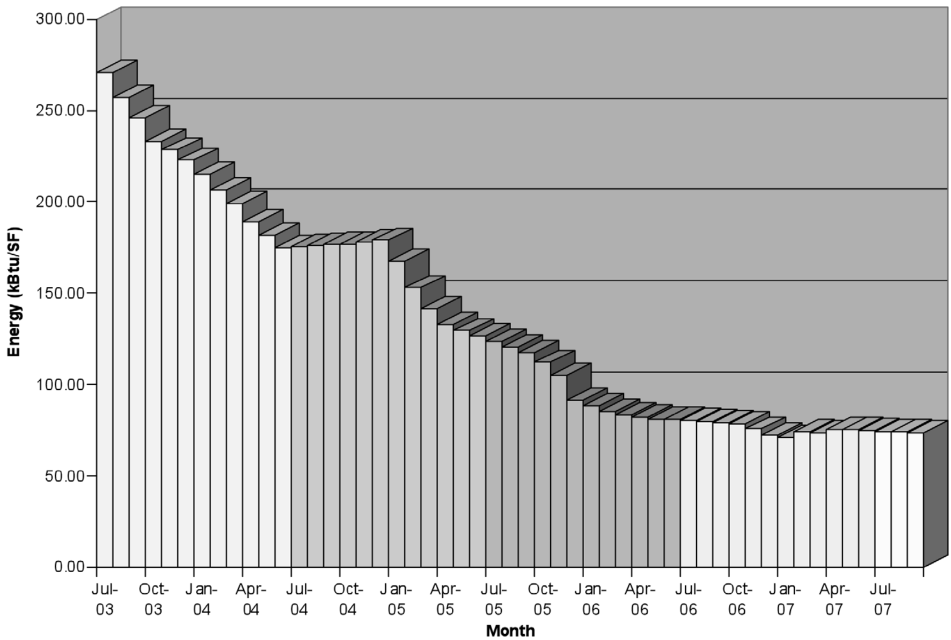


Figure 4: Annual tracking of energy use intensity (EUI)

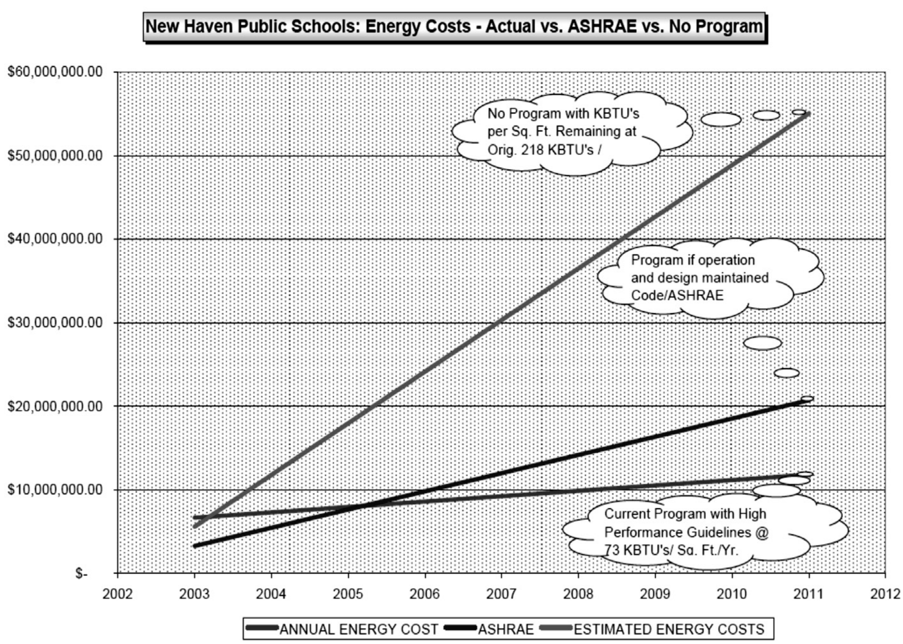


Figure 5. Energy costs—actual vs. ASHRAE vs. no HPB program

CONCLUSION

There is no single path to a high performance building; enhanced collaboration and team commitment is paramount, and experience is valuable in teams designing high performance projects. Energy modeling should be used to inform the design, commission the project, and monitor post occupancy. Measurable goals should be established early and accomplished throughout the duration of the project.

One of the fundamental measures of every good design is that it has to make good business sense, make good environmental sense, be sustainable, and be easy to maintain.

USGBC LEED or similar rating systems should be mandated by government and incentivized. Incidentally, this is the path the CAL-GREEN 2011 is taking.

References

Jason F. McLennan, "The Philosophy of Sustainable Design."

Pickens plan. (2008). http://www.pickensplan.com/theplan/

EIA. (2008). Annual energy outlook (Table A1) Washington DC: Energy Information Administration. http://www.eia.doe.gov/oiaf/aeo/pdf/appendixes.pdf

"Estimating the cost of Environmental Degradation," http://siteresources.worldbank.org/INTEEI/214574-1153316226850/20781069/EnvironmentalDegradationManual.pdf

"Photovoltaics in the built environment," prepared by Solar Design Associates, Harvard, MA.

ASHRAE Advanced Energy Design Guides, www.ashrae.org/technology/page/938.

Los Alamos Design Guide www.eere.energy.gov/buildings/highperformance/lanl_sustainable_guide.html

High Performance HVAC www.highperformancehvac.com

The whole building design guide, "life cycle cost analysis" http://www.wbdg.org/resources/lcca.php

United States Green Building Council www.usgbc.org

ABOUT THE AUTHOR

Mohamed Abaza has over 9 years of experience in HVAC design, energy modeling, energy auditing, and facility assessment, as well as a year of experience in HVAC construction project management and cost estimating. He has worked on some 50 projects, ranging from commercial buildings and schools to high-end residential buildings, private residences, and hotels.

His primary area of specialty is green, energy efficient buildings. Responsibilities have included advising clients and design and construction teams on energy efficient design and construction, best practices, incorporating renewable energy implementation, investigating financial options, and environmental and social impacts.

Mohamed's mechanical engineering degrees include a B.S. from the New York Institute of Technology and an M.S. from the Polytechnic University of NYU. He is a USGBC LEED Accredited Professional and is a certified ASHRAE High Performance Building Design Professional. His practical project experience provides a unique insight into the needs and challenges faced in the facility planning and operations industry, and his experience also forms a solid base for creative, proactive solution planning.

As director of Gilbane's High Performance Building Program, Mohamed oversees the group's service development and quality, client satisfaction, staff management, business development, financial performance, business unit growth, and strategic business direction. His experience and background provide him the skills necessary to successfully manage full program services for numerous projects, including large scale, multi-year, and multi-phase projects.