Performance Persistence

What happens to predicted energy savings from Design Assistance Programs after several years of building operation?

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ABSTRACT

In this study, architects, the sponsoring utility and the energy simulation specialist joined together to evaluate the persistence of energy savings through a Design Assistance Program. The primary question was, “when decisions are made with the help of rigorous analysis in a whole building design process, do the savings persist, or do several years of operation alter the performance of the integrated systems in the building?” To arrive at the answer, three projects—a college library, a municipal transportation facility, and a hospital—are used as case studies.

To define a method for comparison, design simulation and metered performance data were analyzed for specific energy-saving strategies. This paper provides a background overview of the basis of selection of the three projects, the energy design assistance methods employed, the savings expectations, and the decisions made throughout the process. For each case, design characteristics, modeling assumptions, selected strategies and actual metered performance are outlined.

In this evaluation, with three case studies, we find evidence of appropriate levels of energy conservation, but not of the absolute values predicted. In each case, the discrepancies between modeling assumptions and final operating procedures are identified, evaluated and rectified. The paper illustrates that while owners are saving energy, they are not always consistently getting the full savings potential for what they install.

The paper concludes with a reexamination of the overall process and suggests improvements and changes. It evaluates the uncertainty of savings of individual technologies related to utility incentives.

Keywords

Verification, Installation, Energy Savings, Design Guide, Case Study, Commercial Buildings, Project Monitoring

Introduction

Maximizing a facility’s environmental performance requires an integration of architectural, mechanical, electrical and interior design decisions. It is now well accepted by many that a high performance building design results from a series of incrementally beneficial design decisions made collaboratively across the design disciplines. This was not always the case, and there are some architects and engineers who still fear that an integrated comparative design analysis will interfere with their design vision or style.

The building design and construction market is not a single thing. It is a highly differentiated and fragmented marketplace that is both heavily regulated and burdened by social customs. Its complexities are easily underestimated making outcomes more difficult to influence with any certainty than some may be prepared to believe. Four of the common approaches to exerting influence in an effort to transform the market are; code enforcement; teaching “advanced” practices though workshops; promoting efficient components though rebates and; Energy Design Assistance (EDA).

When field verification and validation (VV) or measurement and verification (M&V) are added to EDA services, the combined offering incorporates major components of the other three approaches. Though this paper focuses on the long term persistence of conservation through EDA with VV services, we need to touch on elements of the other three approaches in order to better comprehend the value or limitations of EDA in context.

Code

Energy code enforcement is uneven at best and non-existent in most parts of the country. However, after nearly three decades of providing energy design assistance to the A/E/C professions, we believe that having a code used to establish a minimum practice baseline, clearly raises design standards. Having been on an energy code advisory board for the past two years we have heard our code official colleagues say that none of them would dispute that energy code enforcement is less reliable than commonly assumed. There are very good reasons for this including insufficient budgets for training and inspection. Practicing engineers tell us they believe there is small risk of being tagged for failure to comply with the energy code. Further, they tell us it is always their intention to design to a level better than code – they just don't know by how much they may better the code or whether they will do it in a cost-effective manner. There just isn't enough design fee or money to find out.

A review of the past 280 EDA projects illustrates the current state of the markets continues to be highly variable. Theoretical project "base lines" exceed code by as little as 2 percent or and much as 20 percent depending on building type, initial budget and client and design team sophistication. Engineers have told us that it is only when they participate in EDA projects that they learn how well they may be doing relative to code.

Seminars

Learning is important but short teaching sessions, in the absence of a real application and real consequences has limited retention. Teaching principles to transform the market is an important part of the process; however, much is lost in the translation from classroom to real projects with budgets and schedule deadlines. Teaching technique to transform the market is also an important part of the process; however, the possible failure modes are many like cascading incremental failures or the right techniques applied to the wrong projects. Workshops tend toward indoctrination to principles or training in a technique as an augmentation of code rather than toward an education in critical problem solving which is how the best solutions are developed.

In contrast to the workshop/seminars of, typically, a few hours in a day or two, EDA provides learning connected to real outcomes along with financial reinforcement to collaborating parties. The parties are re-engaged through periodic exchanges over several months. This learning is deep and it is supported by their accountability to each other through measurable outcomes.

Components

Using efficient components is not the same as conserving energy. True energy conservation is the product of both efficient components and the quantity of these installed components. Market transformation using a component approach does a good job of identifying higher efficient components, but does not approach the other side of the equation of how many are used for a given application. Neither mandating efficiencies through codes nor offering incentives for component efficiencies through rebates addresses fundamental design issues that create consumption demands. Moreover, incentive approaches too often only care that a product is used, not that it is used appropriately or well. Building designs where architectural, mechanical and electrical system design decisions are isolated from one another often result in misapplied technologies and non-optimized conservation and efficiency purchases. Component rebate amounts are usually derived as a blended savings value over a very broad market spectrum. We believe that real, cost-effective demand reductions are better achieved through an applied design practice where the values of efficient lighting, pump, motor, chiller and other technologies are interactively evaluated.

EDA addresses efficiency and the quantity of components together. By beginning with building load reduction strategies at an architectural scale, the economics and performance trade-offs of using electrical and mechanical systems to meet the loads can be addressed in the context of both efficiency and quantity/ capacity. There are economic and performance trade-offs and synergies to be made between major system types – architectural, mechanical and electrical – that are not addressed by simply substituting components. The question to be addressed for each component is not "is this component more efficient than my other choices?" but rather, "Is this component with its design application a better value than my other choices to reduce consumption?"

EDA with VV

Energy design assistance begins with an attempt to incorporate the best of all the other approaches to market transformation. A founding premise was to bring everyone with knowledge who was important to the design process to the table. One of the outcomes of this study has been to reveal two open issues regarding knowledge and participation.

Design is as much as social exercise as it is a technical activity. The social dynamics on every design team are different and highly influential on the decision making process. Here is an overview of the social dynamics that impact technical decisions.

Owners only think they know what their new building will be used for. In fact, they are often still evolving their business plans or will ultimately see an unanticipated change in use due to externalities. Beyond that there are these basic truths:

- Any participant in the process can influence any decision through the force of personality and solely on the basis on the basis of a belief in a value without having to prove the merits or the facts of the belief.
- Every participant in the process has a risk position relative to everyone else and manages those risks based on their position, personal goals, specialized knowledge, and personality.
- Every participant in the process has preconceptions and misconceptions about "the right thing to do".
- Every participant in the process has others values in conflict with the values of others.
- Every participant in the process has economic interests in conflict with the economic interests of others.
- Every participant in the process has a limited understanding of how their priorities and choices will impact outcomes important to the other parties
- Every participant in the design and construction process pursues two courses of action simultaneously; evaluating likely outcomes and; keeping their own options open as long as possible.
- Every participant in the process tries to get a larger portion of the overall budget and protect it from others throughout the entire process.
- Every line item of cost is an estimate until the final bill is negotiated by the contractor who will get the most money possible from the owner and pay the least money possible to their subs and suppliers.

- Everything in design and construction is therefore negotiable until it is physically ensconced in the project.

The fluidity of these circumstances cannot be overstated. Design teams operate with a peculiar mix of faith and mistrust in their collaborators. The citing of a code or quoting of a component incentive – correct or not – will pass as acceptable reasons for making decisions in many circumstances without any real comprehension of value. EDA as an educational and collaborative process bridges design disciplines to reveal opportunities to assess and evaluate integrated code, conservation and efficiency choices to get at best practices on a case by case basis. Perhaps most importantly, there is buy-in to the solution by the majority of the people at the table.

But, not everyone is at the table. Energy design assistance generally happens in the early to mid design cycles. But, without verification and validation (VV) of the decisions, the intentions may go unrealized. For every individual at the table making commitments there will be another 3 to 5 people carrying out their intentions. Many of those people are capable of altering the intended outcome. The VV process helps assure that the conservation and efficiency measures remain in the project and are properly implemented in later design documents and in construction.

Developing EDA and VV together over the past 14 years has resulted in moving the average rate of implementation compliance from 40 to 98 percent in participating projects. This means that the average participant does 98 percent of what they say they will do. The balance of this paper looks at the question "Then what happens?"

This paper looks at the effectiveness of adding energy, daylighting and other environmental strategies to the design evaluation discussions across disciplines, from the perspective of three different participants. This was largely an unfunded exercise driven by a simple desire to know if we were collectively doing well. Everyone, including the building owners, gave freely of their time and placed themselves in each others trust to develop this information. An effort was made to select projects where we suspected an outcome different form what was modelled.

Overview of the Energy Design Assistance (EDA) Program

The State of Minnesota, its largest utility and area leaders in architecture and engineering began an integrated design effort in earnest in 1989 with four pilot projects at the University of Minnesota. BWBR Architects was one of the pioneering firms electing to take part in an experimental design process to bring design disciplines closer together in a collaborative effort to alter traditional interactions between the client, architects, engineers, interior designers and the energy provider. The underlying premise was that, although knowledge of sustainable practices and technologies existed within each group, cross-disciplinary evaluations were not occurring. In 1989, there were no design process mechanisms to evaluate advanced architectural alternatives against advanced mechanical or electrical strategies in a timely manner, and first cost was usually the only evaluative metric.

Energy Design Assistance (EDA) is a Minnesota Xcel Energy electric and natural gas conservation program that promotes the installation of energy efficient strategies in new construction and major renovation projects. The Custom Consulting level of service offers design assistance through a sophisticated consulting process that includes computer modelling of the planned design, funding to offset the cost of design time associated with the increased energy analysis, financial incentives to improve the cost effectiveness of a package of energy efficient measures, and field verification that the strategies are installed and operating properly.

The program's genesis dates back to 1989 at the University of Minnesota from Exxon overcharge funds. It officially moved, in 1992, to be included as the "Energy Assets Program" in the utility firm then known as Northern States Power Company's portfolio of conservation programs. Starting its 14th year at now Xcel Energy, Energy Design Assistance has:

- Provided valuable information to over 230 building projects
- Yielded a combined $20 million in annual customer energy cost savings
- Avoided approximately 60 MW of electric demand production at system peak
- Provided $10 million in incentives for efficient strategies
- Worked with over 200 architects and engineers
- Avoided approximately 20 tons of air emissions annually from related power production
- Reached nearly 50 percent of the target building market
- In 2003,"Exemplary Program" (natural gas) – ACEEE

Reasons to Collaborate

The key to the success of this program is always the relationships with architecture and engineering firms. Trust in the provider and value in the service has enabled the program to maintain growth for 14 years. In addition, clients of the design team who are also customers of Xcel Energy benefit from valuable information and cash incentives.

Xcel Energy recognizes the savings potential associated with including efficient strategies in the construction or renovation of a building. They also recognize that building owners have budget constraints and information constraints that create barriers to fully exploring, and/or pursuing the implementation of, these strategies. Although they have the funding and analysis that says this is a good idea for the environment and for our energy customers, they do not have the relationship, opportunity, or expertise to get building owners to act. This is why Xcel Energy proactively works with other design industry experts who are trusted to bring ideas to the table through professional relationships, energy modelling experience, and expertise in the process.

In 1990, BWBR Architects collaborated with The Weidt Group in the design of the Basic Sciences & Biomedical Engineering Building for the University of Minnesota – a pilot project for a program that grew into the Energy Design Assistance program. Since that time, BWBR Architects refers to the process of producing sustainable, environmentally responsive buildings as Performance Design. Their commitment to this philosophy means designing buildings that make efficient use of energy, water, and building materials while creating healthy and productive environments for our clients. They work with the Energy Design Assistance program whenever possible, to explore options for maximizing energy efficiency, minimizing operating costs, and to select options for design based not only on client goals, but also on environmental responsiveness and proven long-term energy savings.

The Weidt Group has been providing design assistance in energy, daylighting and sustainable design for 26 years. The staff from The Weidt Group responsible for developing Energy Design Assistance with Xcel Energy had all, at one time, been well-established practicing architects or engineers. The fundamental premise behind Energy Design Assistance is that design teams desire to know the potential benefits and liabilities of the choices they may make, but have limited time and budgets with which to comparatively analyze options in depth. Consequently, there is a continued institutional reliance on standards for guiding design outcomes. This reliance also means a diminution in skills for comparative analysis on the part of many professionals.

The Weidt Group provides these skills to the design team when they need them the most. Using the architectural design team's in-depth knowledge of the client, including factors such as the facility program, project budget and client-appropriate technologies, The Weidt Group guides the team through a comparative analysis of alternate projections and outcomes using sophisticated computer-modelling tools for energy, lighting and daylighting. Xcel Energy supports these collaborations through its Energy Design Assistance program.

Exploration of Energy-Saving Options During Design

Project Inception

At the start of every project, there is concern regarding the ability to accomplish basic design and coordination efforts within established timeframes and professional fees. There is also firm knowledge of what codes will require and ideas about advanced energy and environmental options. The Energy Design Assistance (EDA) program provides project teams with an investigative structure, financial resources and performance modelling so that they can design and test alternative strategies. EDA is intended to ensure that design efforts and construction dollars are directed to those strategies providing the greatest measurable benefit. The program's analytical process evaluates strategies on the basis of annual energy savings, peak energy reduction, pollution abatement, upfront costs, and payback on investment over time. This information enables design teams and clients to make informed decisions about different energy saving strategies.

It is very important to note that the process is designed to promote and predict savings rather than consumption. For this reason, when an owner selects a design solution, they can expect to save a percentage of their operating cost rather than a fixed amount of money every year. Like driving a more fuel-efficient car, the amount you save depends on how much you drive. This fact is often forgotten by the end of construction as this paper demonstrates.

Preliminary / Schematic Design

As the design team works its way into the project, basic site and building operating parameters are established regarding proximity, access and functionality. EDA is rarely directly applied at this stage of design. Although many of the basic site and orientation decisions made here are evaluated through EDA, they are only occasionally changed through the evaluation. Of the decisions made at this point, the ones more likely to be influenced are those pertaining to fenestration, insulation and perimeter vs. core functions. Most importantly, the design team is establishing the baseline for the comparative analysis to follow. At some point near the end of Schematic Design, a thermodynamic operating model can be constructed from the basic geometry of the "Base Case." This model serves as both the basis for a code analysis and cost evaluations.

It is from here that the project design and operating characteristics are estimated with the client and tested against an array of climate responsive and energy efficient strategies, including glazing, daylighting, lighting, insulation, cooling, heating, and outside air. The use of the building and its operating characteristics, as defined by the owner through the design team, are the foundation of the energy modelling assumptions.

In a meeting that lasts from one to two hours, the collective experience of the team is used to collaboratively establish the range of variables for the preliminary assessment of strategies. The group's first objective is to identify the variables that anyone on the team believes will have a beneficial performance impact on energy and environment. The next step in the discussion is to bracket each strategy with possible performance ranges – because ultimately, we are looking for the best value from an interactive set of variables. For example, the very best product in a particular category may not be the very best value because its level of performance is never demanded due to other design decisions.

Design Development

Early in this phase, project details are further resolved. Data and assumptions on what is to be modelled are exchanged. It is crucial that modelling reflect the best knowledge available about how the design will be resolved and how the building will be operated. The interaction of systems and components is studied through hourly performance simulation models. Energy, daylighting and other sustainable design strategies are further developed and tested.

In a second two-hour meeting, the design team and owner associate strategies into “bundles” wherein the combined benefits and interactive effects of strategies (such as daylighting and light control strategies compared with chiller options) can be assessed. Estimations of incremental costs (costs associated with employing the identified strategy over those of the “base case”) are assessed and considered in concert with reduced consumption, peak load, and associated operating costs.

Refinement models are then run, and at a third meeting- the completion of this study- owners (with the design team) are asked to make a formal commitment to Xcel Energy to incorporate one of the tested “bundles” of strategies, and in turn, Xcel commits to a financial incentive for the owner.

Construction Documents

In preparation for construction, efforts are directed towards completing the technical details and coordination of strategies identified in the selected bundle. The documentation developed during the EDA process serves as a useful guide and checklist in coordinating the efforts of design team members. In the event modifications are discovered necessary, these are communicated to the design team, The Weidt Group, and Xcel Energy so that performance projections and financial incentives can be appropriately modified.

Construction

In this phase, the incorporation of strategies into the construction documents and ultimately into the project, are verified through an independent review of the construction documents, shop drawings, product submittals, and on-site verifications.

Verification and Validation

On-site verifications periodically continue after occupancy to monitor whether the energy conservation strategies installed are working properly. It is important to note this effort is not a substitute for a commissioning process, which should ideally be planned and incorporated into the project’s schedule and budget from the start. Verification and validation efforts are a prerequisite to Xcel’s payment of financial incentives to the client.

Selecting Projects

BWBR Architects, The Weidt Group, and Xcel Energy have worked together to apply the Energy Design Assistance program to numerous projects during the decade since the program’s inception, including both new facilities and renovations of existing buildings. It was anticipated that lessons learned from completed projects could be used on projects which were underway.

Completed Projects

- Basic Sciences & Biomedical Engineering Building, University of Minnesota
  New 262,000 gross square feet (24,340 m^2), $51 million (39,131,436 Euro) science laboratory building housing more than 500 researchers, completed in 1996
- James G. Lindell Library & Information Technology Center, Augsburg College
  New state-of-the-art, $9.2 million, 73,000 s.f. library for the digital information age, completed in 1997
- East Metro Transit Facility, Metro Transit
  New 333,000 s.f., $34.7 million transit company office, storage and maintenance facility, completed in 2001
- Woodwinds Health Campus, HealthEast Care System
  New, nationally acclaimed $34 million medical campus including a 185,000 s.f. hospital, completed in 2000
- Lawson Commons Corporate Office Tower, Frauenshuh Companies
  New 13-story, $32 million office building in downtown St. Paul, completed in 1999

- Regions Hospital Expansion 2000, HealthPartners
  $35 million expansion of a major urban hospital as a hospitality-based healing environment, completed in 2000
- Fairview Southdale Hospital Outpatient Services Expansion, Fairview Health Services 160,000 s.f., $39.5 million expansion and remodelling to create new public entry spaces and a world-class cardiology centre, completed in 2002
- Saint Ambrose of Woodbury Catholic Church and School
  New 110,000 s.f., $13.1 million campus with a worship centre and K-8 Catholic school, completed in 2000

Creating a Shortlist for Study

The team identified eight possible projects based on a range of criteria including age, building type, market segment and knowledge of potential interest by the building owner. The initial list included three hospitals, a transit facility, a college library, a public/private venture office building, a church and a public university building.

In an effort to demonstrate long-term savings, we chose the four projects for an extended energy performance verification and validation study, based on their respective forensic challenges and market forces. In order to qualify, a project needed to be have been completed and operated for at least one year. It also needed to be new construction and have clearly identifiable energy metering because additions to existing buildings (and buildings on central-plant campuses) are much more difficult to evaluate. Multi-metered or shared metered buildings on campuses were generally ruled out because of the time it would take to get clean data. Permissions from building owners to receive, analyze and report their energy usage data were also required. Through the short listing process, we identified two owners whose perceptions of their building performance were not completely satisfactory based on their expectations. For those whose buildings were not selected for the study, other follow-up meetings were held to understand their questions and concerns. The best candidates were a hospital, the transit facility, public/private venture office building and the college library.

The college library is a stand alone, single meter, private campus facility with nearly 8 years of data. The design included aggressive daylighting and occupancy controls and the owners were very interested in a long-term follow-up. This state-of-the-art building bridges the rich heritage of the traditional library environment with the digital information age. The 73,000 s.f. four-story facility brings library collections, information technology, an art gallery, college archives/special collections and learning labs together in a high-tech academic centre. Technological amenities include network and data access, multimedia capabilities, satellite linking, and computer labs. Energy saving options implemented as a result of the Energy Design Assistance program include stack light controls and variable air volumes that respond to occupancy levels, perimeter-only light switches that can be turned off with adequate daylight (strategic switching), and highly efficient mechanical/electrical equipment. The $9.2 million building was completed in August 1997.

The hospital is a private sector, stand alone hospital and clinic facility with multiple investors and design teams. It was thought to have a single meter, or at worst, two well-defined metered areas. This complex, equipment intensive building type is representative of a growth market which often has dynamic program elements. This new $43.4 million freestanding medical campus is touted as one of the nation’s most progressive new models for health and wellness facilities. Completed in 2000, the 201,000 s.f. campus includes a hospital, emergency care centre and outpatient surgery centre; outpatient rehabilitation and a day care centre; and an 80,000 s.f. medical office building. As architect of record for the exterior shell, BWBR introduced the EDA program to the project team, leading to energy savings achieved through light fixtures outfitted with occupancy sensors, daylight controls, and energy efficient HVAC systems. BWBR also produced the construction documentation and provided construction administration services.

The transit facility is a simple transportation storage and maintenance facility with a single public sector owner and a lean design team. It is not a high growth market but it is a stand alone, single meter facility with a motivated client. Completed in September 2001, this new $28.5 million facility was designed with an emphasis on sustainable design strategies, including indoor air quality and energy efficiency. The 333,300 s.f. facility, plus roadways and parking, sits on a triangular 597,000 s.f. Brownfield site that required extensive soil clean-up prior to construction. The building's three main components include a bus storage area, a bus maintenance area and roughly 18,000 s.f. of administrative space. Giving workers a pleasant work environment was a priority, so special attention (including extensive daylighting studies) was paid to materials and finishes, comfortable spaces, indoor air quality and natural light. Light monitors in bus storage and maintenance areas, diesel emissions sensors, efficient window glazing, perimeter-only light switches, sensor-operated light fixtures in little-used rooms and mechanical systems were designed to maintain a high air quality standard and maximize operating efficiencies. To reduce transportation and energy costs, all materials for the building's exterior were obtained from within a 150-mile radius of the project site.

The public/private venture office building was considered because it represents a basic building type. There were complex metering issues and permissions which would need to be resolved. This full-block $53 million development in the heart of historic downtown St. Paul houses the world headquarters of a primary tenant with more than 700 employees. The complex includes a 450,000 s.f., 13-story office tower with an attached 1,000-vehicle parking ramp and a street-level retail arcade with restaurants, a coffee shop, a bank and a bookstore. Brick and stone were used to create harmony with surrounding historic buildings, while glass and metal elements express the client's high-tech image. The EDA program led to energy saving strategies such as window glazing, increased wall insulation, efficient mechanical equipment and scheduled outside air. The facility was occupied in December 1999. In the end, though we did try to include this public/private venture office building in spite of its complexities, it was eliminated due to time.

Performance Data

Preparation

In order to achieve valid results, several data verification and normalization steps were required. Metered data had to be confirmed as being correctly applied to physical location and square footage. (For example, multiple meters may have been installed for billing purposes at a single building address; accounting for only one would skew the results.) Operating characteristics such as operating hours, equipment load and system settings assumed for the building and typically established at the end of the schematic design stage, needed to be reconfirmed. Operating longer hours or at different outside air settings than originally modelled during the design process would result in different "real-world" usage/energy savings results, just as changing from basic office space to a computer or call centre would throw off results. Weather normalizations may also be required. And, in addition to dollar savings, energy end uses were evaluated by energy type.

Data and Interpretation

Figure 1, below, is the general format for all the data presented. The top blue line with the diamond markers indicates the code level performance anticipated by the energy simulation model while the light blue line with a square marker indicates the energy simulation model prediction for the selected bundle of conservation strategies. The line with the "x" marker is the predicted as-built performance based in the model. Finally, the burgundy line with the circular marker illustrates the metered results.

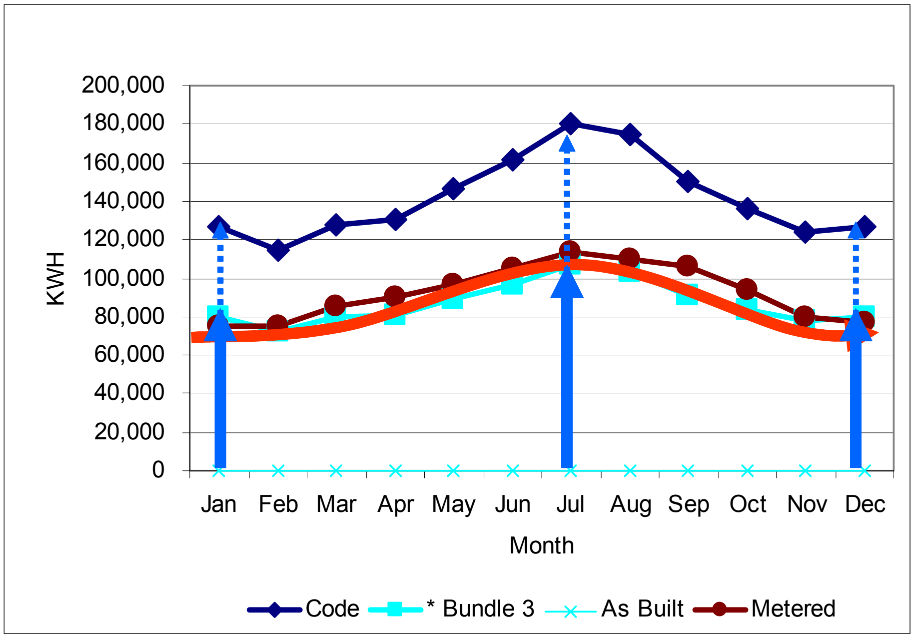


Figure 1: Illustrative Data

We first check to see if the As-built, Bundle and Metered lines have the same shape (shown by the thick smooth line in Figure 1). If they do, then we may generally conclude that we have modelled overall behaviour of the systems and operations correctly. Next we look for magnitude. We are looking for the overall distance between the Code Line and the performance lines; the area between them indicates savings. Where the lines are off in shape or magnitude, there are issues to investigate.

College Library

The projected energy savings for this facility was 40 percent compared to a code base. With an incentive from Xcel Energy, the payback was projected as 1.6 years. Library lighting design and mechanical strategies included: reduce lighting levels in reading areas and office/workstations; daylighting of perimeter study and office work areas; occupancy sensors at collections, archive, and small rooms; reduce glass area; fan powered VAV boxes; schedule for no outside air (OA) at night; variable speed water pumps; occupancy sensor control of OA and VAV boxes; premium efficiency motors; cooling temperature setup schedule; perimeter/ core air handling units and dual chillers.

Performance Results

The measure of consumption, kWh, is the largest component of the owner's electrical bill. Upon opening, consumption appears in alignment with modelled predictions.

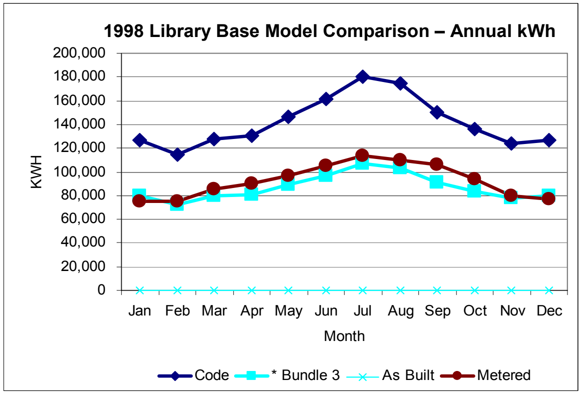


Figure 2: Library Findings kWh Performance 1998

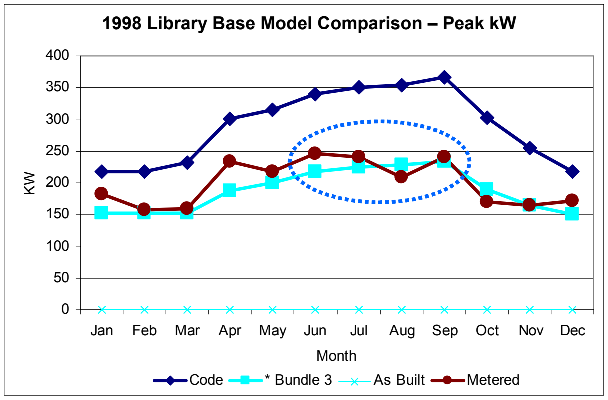


Figure 3: Library Findings kW Performance 1998

The measure of maximum demand, kW, for a given time period generates a "peak demand charge" in the owner's electrical bill. Upon opening, Figure 3, peak kW, though harder to predict, tracks very well with the selected bundle. Predicting peak kW is an attempt to estimate a worst case moment for controlled and uncontrolled systems.

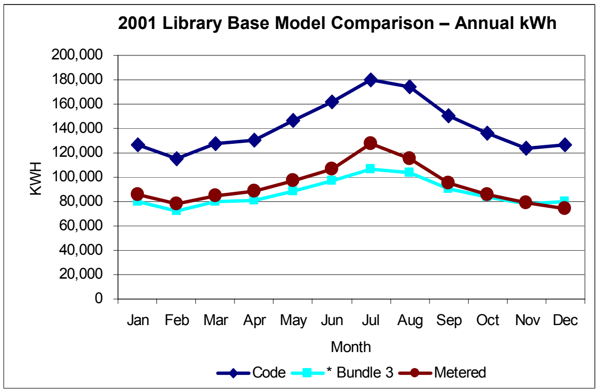


Figure 4: Library Findings kWh Performance 2001

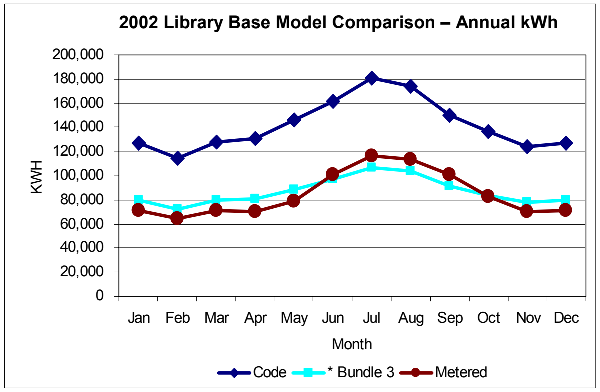


Figure 5: Library Findings kWh Performance 2002

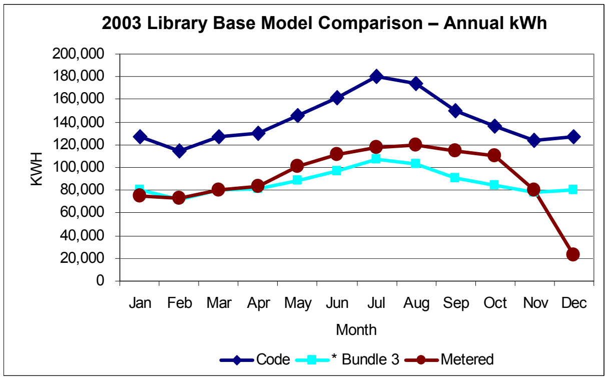
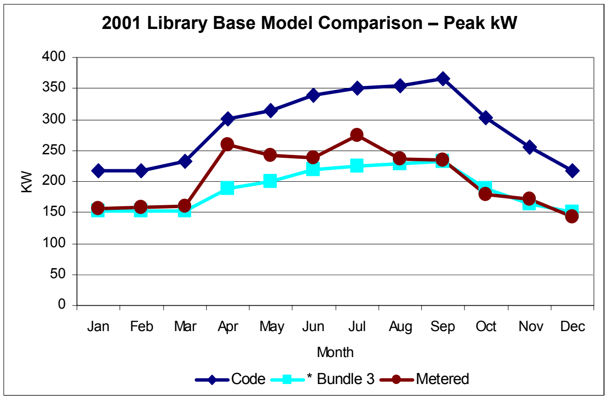


Figure 6: Library Findings kWh Performance 2003

The kWh numbers remain well within excellent ranges though 2002. New loads, longer hours or weather may be factors in some of the curve fluctuations, but these curves still have "great shape" and magnitude. In 2003, kWh begins to go a little "off course" in the summer and it is tentatively attributed to longer hours and a hotter summer.



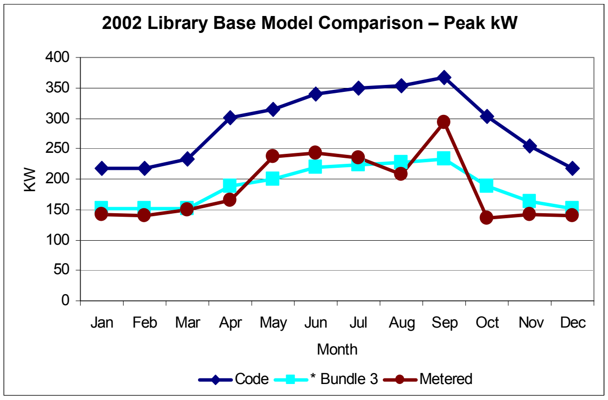


Figure 7: Library Findings kW Performance 2001

Figure 8: Library Findings kW Performance 2002

In spring 2001, actual building peak kW was higher than expected. In April, May, June a pattern like 1998 re-emerges, which could be due to an unknown activity, operational change, seasonal unpredicted load or incorrect operational assumptions in the model. Operations return to predictions in August. In September 2002, actual building kW use was higher than expected and in summer 2003, actual building kW use was less than expected. A simple telephone call to the building operator / facility manager resolved most of the issues.

After the departure of the original building operator in early 2002, the new building operator changed operating limit on the first of two chillers from approximately 80 to 100 percent before allowing second chiller to start. Running a chiller to 100 percent of capacity is like winding out the transmission on your car before shifting gears. As the motor ”winds out” its efficiency decreases. Another new building operator was hired in late 2002 and changed first chiller back to a maximum part load operations of 80 percent, resulting in energy savings. Figure 9 shows that in late summer 2003, actual building kW was less than expected and yet the newest building operator changed operating limit of first chiller again from 80 percent down to 60 percent resulting in operations at a more optimum energy savings. Incredibly, all three building operators were making decisions without ever seeing the utility bills. The current building operator was surprised and thrilled to know that his choices were visible to us and have made a positive difference.

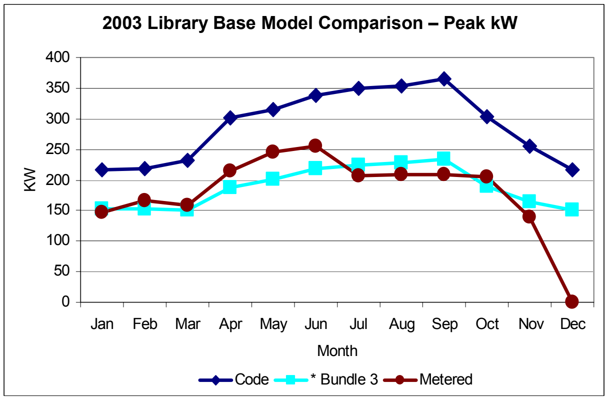


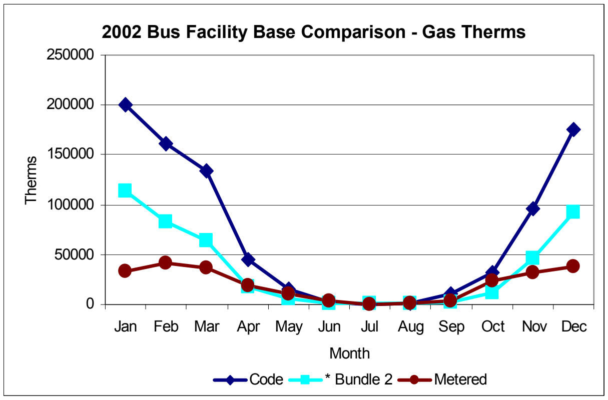
Figure 9: Library Findings kW Performance 2003

Transit Facility

The projected energy savings for this facility was 27% compared to a code base. With an incentive from Xcel Energy, the payback was projected as 9.3 years. Energy conservation strategies included: private office dual level switching; conference/ training dual level switching; locker room occupancy sensors; storage/ restroom occupancy sensors; vehicle storage central sweep and vehicle maintenance central sweep; private office direct lighting at 70fc; conference/ training direct system at 70fc; vehicle storage at 20 percent reduced lighting density; vehicle maintenance at 10 percent reduced lighting density; air cooled DX units at 10 percent improved energy efficiency ration (EER), gas boiler 85 percent efficiency, premium efficiency fan motors, variable speed drives on fans and pumps, air quality control of fans, sensible heat recovery and, occupant control of VAV/ outside air with variable speed motors.

Performance Results

Gas energy use is significantly lower than modelled results. If these savings are real, then we can use actual circumstances to adjust the model



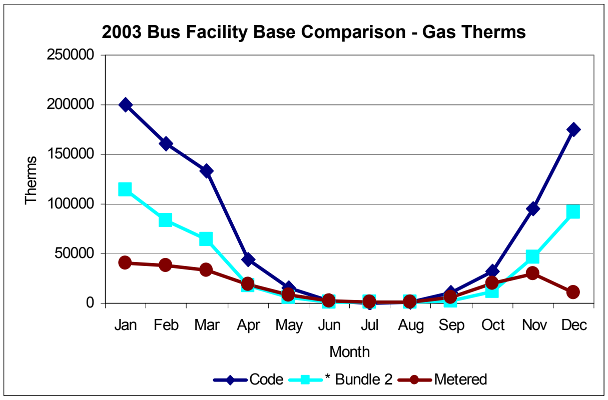


Figure 10: Transit Findings Gas Performance 2002

Figure 11: Transit Findings Gas Performance 2003

The original model of outside ventilation air in the vehicle storage area, based on information from the design team, was higher than actual operational levels. The model had 100 percent outside air for 12 hours/day and 30 percent outside air for all other hours. Actual operations based on a final design called for 100 percent outside air for 2 hours/day and 20 percent all other hours. The actual building operators made changes after initial models were built and are making use of CO controls to address diesel fuel issues more rapidly and cost effectively. This solution uses much larger fans for a shorter period of time. It stretches the code and changes the code base of the building. A similar change was made to the original modelling of outside ventilation air in the vehicle maintenance area. The model was based on original intention to use 100 percent outside air for all hours, but the actual operations use 40 percent outside air for all hours and make use of the CO monitors as well.

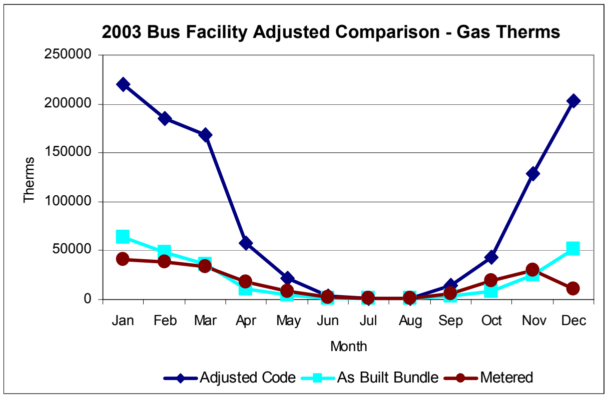


Figure 12: Transit Findings Gas Performance 2003 As-Built

The accuracy of savings estimates is highly dependent on getting accurate operating intentions made by the owner/end user and design team. The code base in any building is a variable. The code base for the as-built model was modified to reflect the design and operating changes made after the initial model. Figure 12 shows the adjusted prediction. Had the design team and owner consulted with the modeler after the design had been changed, the larger savings would have been predicted. When a utility incentive is tied to predicted savings, the owner may benefit with a shorter payback period. The operating lesson learned here has since been applied to two later projects.

Hospital Facility

The projected energy savings for this facility was 55 percent compared to a code base. With an incentive from Xcel Energy, the payback was projected as 2.6 years. Energy conservation strategies included: Low-E special tint windows; lighting controls in storage/mechanical/toilets, exam rooms, lounges and prep areas; office lighting reduced to 50fc; exam lighting power density reduced; dual stage electric and gas absorption chillers; 83 percent efficient gas boiler; premium efficiency fan motors; variable speed drives; CO_2 control of outside air; and occupant control of outside air.

Performance Results

Initial data indicated that the building uses significantly more gas and electric energy than expected. We immediately noted a contradicting change – hospital occupancy was 60 percent of projected use. This is a complex economic engine with many variables and significantly more equipment load than our other examples. In addition to investigating the actual installed equipment and usage, we would need to investigate plug load usage, elevator usage, exterior lighting, interior lighting and domestic hot water.

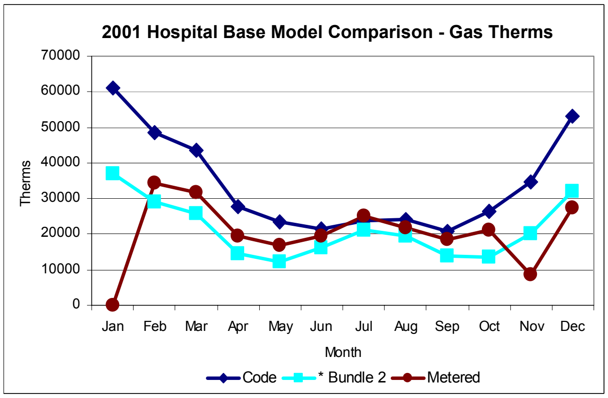


Figure 13: Hospital Findings - Gas Therms 2001

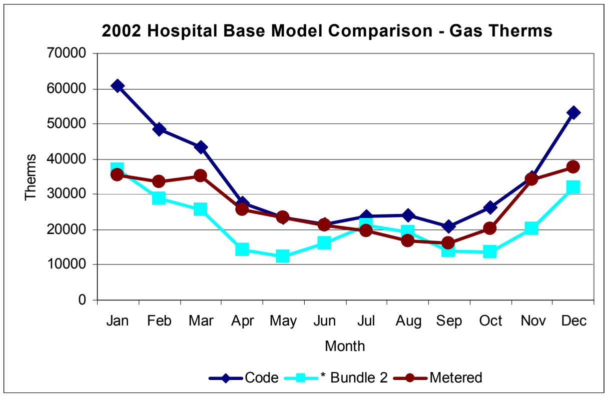


Figure 14: Hospital Findings - Gas Therms 2002

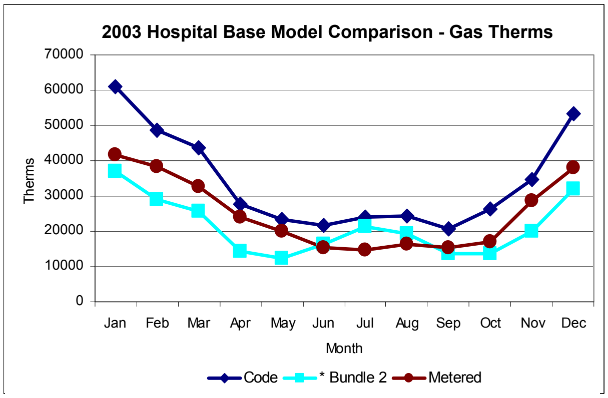
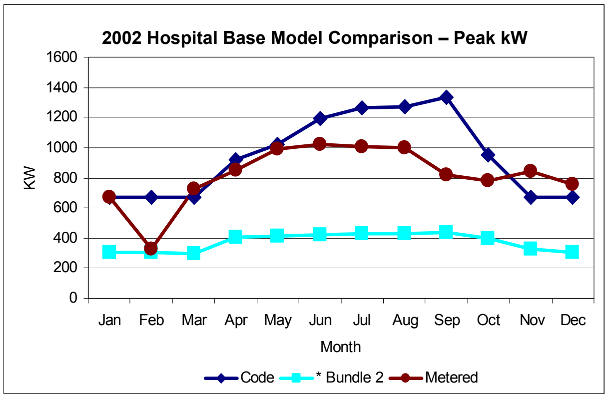


Figure 15: Hospital Findings - Gas Therms 2003

Looking at the figures above, in 2001 the general shape of the bundle and metered curve are similar, but by 2002 the meter curve looks more like the code shape and this may be due to estimated meter reading. In 2003, it seems likely that operations may not be following the conservation plan.



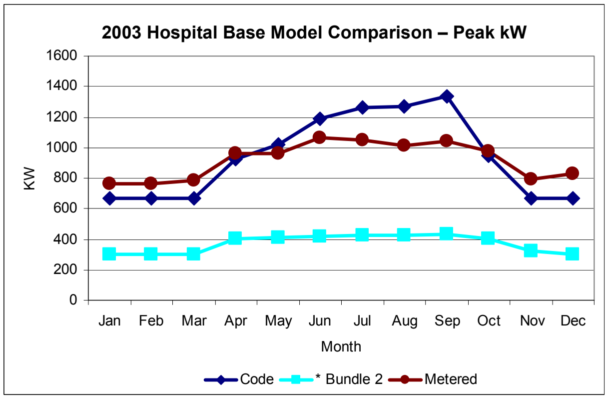
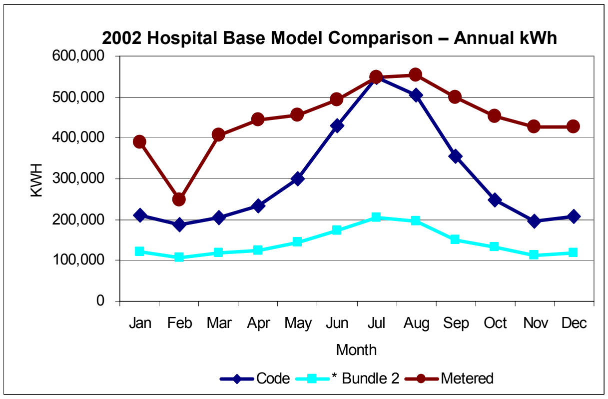


Figure 16: Hospital Findings – Peak kW 2001

Figure 17: Hospital Findings - Peak kW 2002

In 2001, erratic meter readings for both peak kW and kWh suggested estimated bills. However, in 2002 the curve begins to take on the right shape, but, ruling out an extreme change in the weather, the magnitude suggests un-modelled loads or radically different operations. Again in 2003, the metered curve has the right shape but wrong magnitude.

In 2002, the kWh curve, in Figure 18 below, begins to take on the right shape, but again ruling out weather, the magnitude suggests many un-modelled loads. Again in 2003, the curve has the right shape but wrong magnitude.



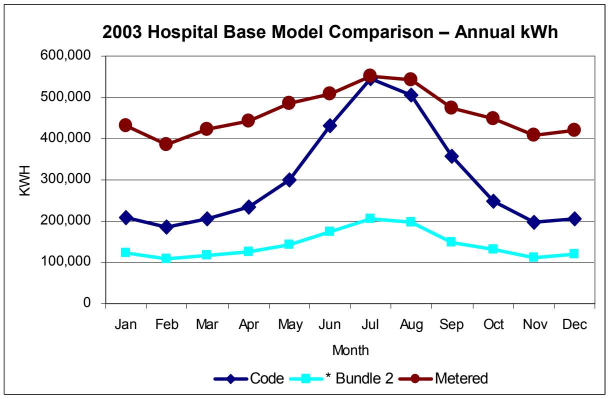


Figure 18: Hospital Findings – Annual kWh 2002

Figure 19: Hospital Findings - Annual kWh 2003

Review of Operations and Model

We easily identified more equipment loads, more lighting and longer operating hours. Daylighting controls were not in use and the hospital had 60 percent longer daily operating hours. The operating rooms are maintained at 50 percent relative humidity (RH) all year and all hours, and are run as though occupied from 7:00 a.m. to 7:00 p.m. Monday-Saturday. The unoccupied temperature is only a 3^{o}F (16.11 ^{o}C) increase from occupied. These are significantly different conditions from those discussed during design.

There were many other changes, including larger than expected supply fans and outside air levels not being reset based on CO_2 controls. And, like the library, the first of two electric chillers is run to a fully loaded 300 tons rather than 150 tons, as modeled, before the gas absorption chiller is used. There were many other lesser adjustments to the as-built model that were needed covering all facets of design and operation.

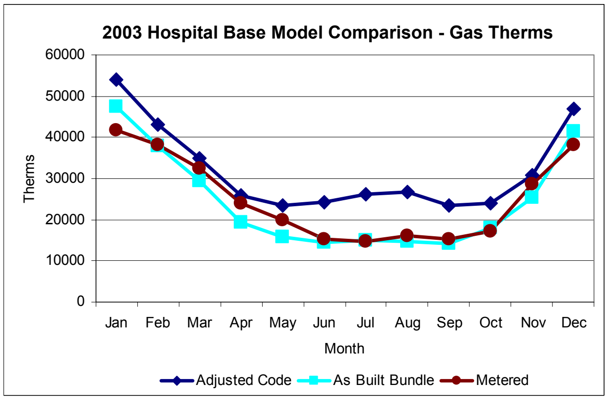


Figure 20: Hospital Findings - Gas Therms As-Built 2003

The adjusted as-built model for 2003 closely matches current operations with the building operating at better than code in the summer and roughly at code levels from fall through spring. For peak kW, the 2002-03 curves have excellent shape and magnitude suggesting field investigations and adjustments are valid.

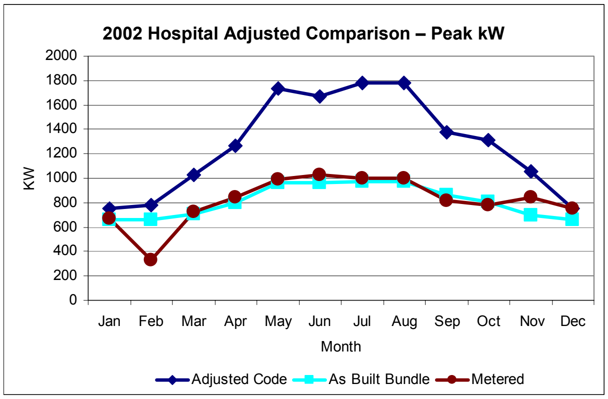


Figure 21: Hospital Findings – Peak kW As-Built 2002

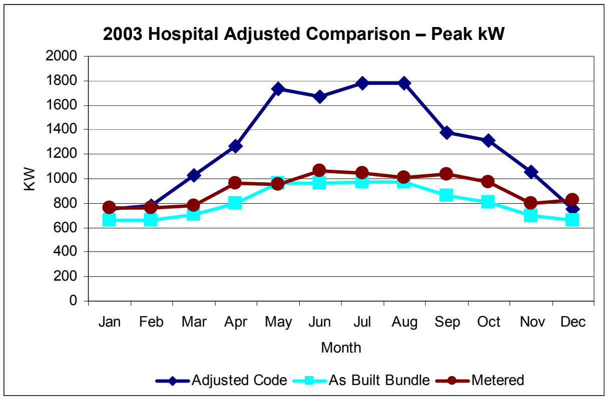


Figure 22: Hospital Findings - Peak kW As-Built 2003

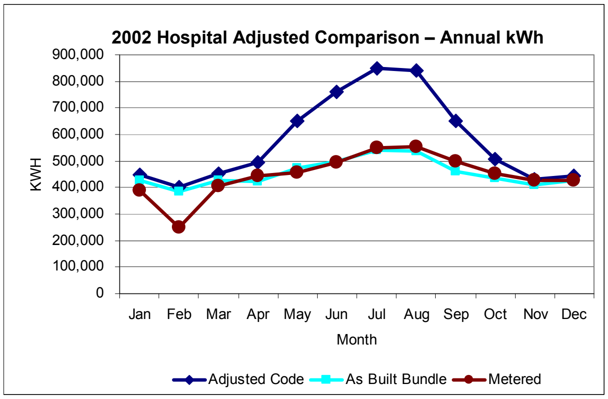


Figure 23: Hospital Findings –kWh As-Built 2002

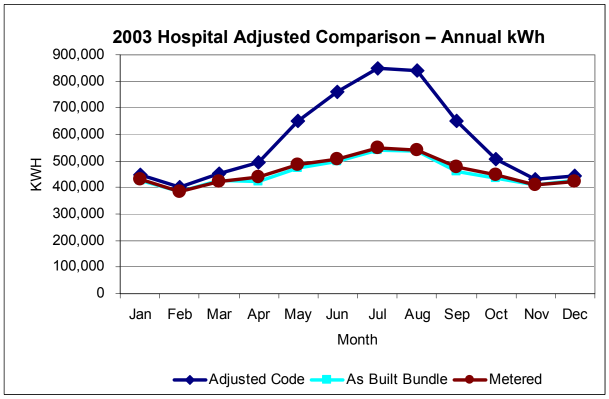
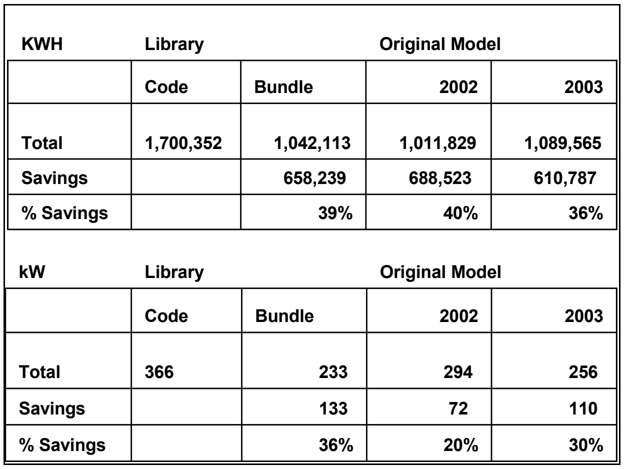


Figure 24: Hospital Findings - kWh As-Built 2003

The kWh curves for 2002 also to take on the right shape and magnitude suggesting properly adjusted and modelled loads. The owner is seeing significant annual savings

Conclusions

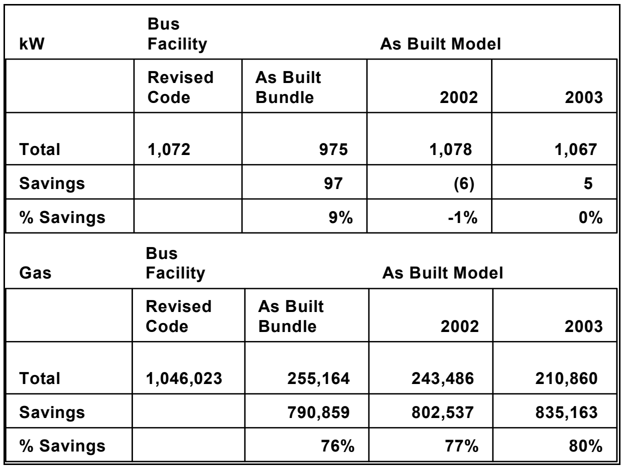
All projects incorporated strategies selected through the EDA process. Not all implemented them fully or operated the building as expressed during the design process. The library did not require an adjusted or as-built model to rectify differences. Predicted and actual savings have remained close since 1998. The worst kWh prediction in 6 years was 3 percent off while the isolated worst kW prediction for a single month in 6 years was off by 16 percent in the non-critical month of April. For the transit facility, an as-built model was required. Once completed, it predicted savings performance in peak kW and gas consumption within 10 percent and 4 percent respectively.



KWH	Library		Original Model	
	Code	Bundle	2002	2003
Total	1,700,352	1,042,113	1,011,829	1,089,565
Savings		658,239	688,523	610,787
% Savings		39%	40%	36%

kW	Library		Original Model	
	Code	Bundle	2002	2003
Total	366	233	294	256
Savings		133	72	110
% Savings		36%	20%	30%

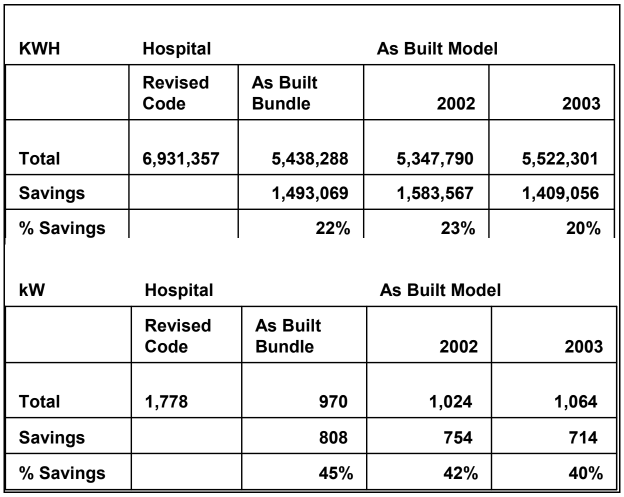
Figure 25: Library Findings



kW	Bus Facility		As Built Model	
	Revised Code	As Built Bundle	2002	2003
Total	1,072	975	1,078	1,067
Savings		97	(6)	5
% Savings		9%	-1%	0%

Gas	Bus Facility		As Built Model	
	Revised Code	As Built Bundle	2002	2003
Total	1,046,023	255,164	243,486	210,860
Savings		790,859	802,537	835,163
% Savings		76%	77%	80%

Figure 26: Transit Findings – Adjustment Impacts



KWH	Hospital		As Built Model	
	Revised Code	As Built Bundle	2002	2003
Total	6,931,357	5,438,288	5,347,790	5,522,301
Savings		1,493,069	1,583,567	1,409,056
% Savings		22%	23%	20%

kW	Hospital		As Built Model	
	Revised Code	As Built Bundle	2002	2003
Total	1,778	970	1,024	1,064
Savings		808	754	714
% Savings		45%	42%	40%

Figure 27: Hospital Findings – Adjustment Impacts

For the hospital facility, an as-built model was required. Once completed, it predicted savings performance in peak kW and kWh consumption within 3 percent and 5 percent respectively.

We began this undertaking with a fairly open premise – see what we can learn. Our very early history with Energy Design Assistance taught us that EDA with later field verification alone yielded about 40 percent compliance in the implementation of Energy Conservation Measures (ECMs). For the past ten years, with advanced warning to the design team, we have been implementing a series of document reviews prior to the beginning of construction whenever possible. These periodic checks have routinely returned an average compliance rate of 94 to 98 percent in the implementation of ECMs. In the broadest sense, these figures may be seen to validate the premise that early Energy Design Assistance with periodic reviews and field verification yields consistent results.

And then, there were the other projects. We tried to select at least one project whose early history was known to have been excellent and others where we suspected there were issues of compliance and performance. There were both narrow and broad lessons learned from these investigations.

1. It is not uncommon for facilities operators to make operational decisions with limited or non-existent feedback on the economic or energy implications of their actions.
2. If at all possible, facilities managers should attend design and EDA meetings.
3. It is possible that some engineers in the process of participating in the EDA process are not telling us what they actually plan to do.
4. Transit facilities can, and possibly should, be designed to operate in a manner not entirely anticipated by code.
5. It is possible that the more complex the business team assembling a building, as in the case of the hospital, the more likely that the end use will vary from the model.
6. It may be best to re-simulate all buildings near the end of contract documents and/or at the end of construction.

Since our objective was to look for clues to offering better consulting services to insure better results and higher participant satisfaction, we are pleased with what we now have to think about.