A Scalable Approach to Energy Improvements

Using Energy Management and Control Systems

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ABSTRACT

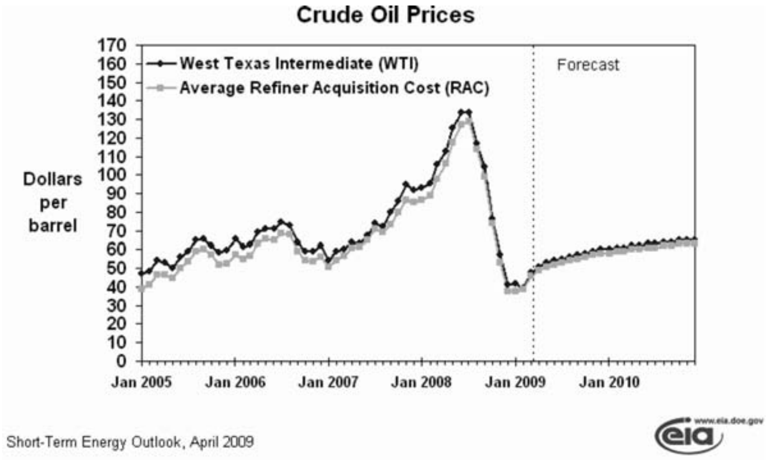
Energy management and control systems (EMCS) for the commercial building sector have undergone dramatic changes over the last decades. Nevertheless, they provide inadequate assistance to owners and operators when it comes to managing energy. Their prime focus has always been managing equipment, rather than managing overall building performance. With a renewed national and international focus on building energy consumption, and ambitious targets set by various governmental agencies, systems now have to shift from managing equipment to the much larger picture of providing a useful tool in the context of managing a national energy policy.

This article aims to illustrate some of the challenges faced by the engineering, construction, and building operator community when it comes to meeting new state and federal guidelines on energy efficiency.

A FOCUS ON ENERGY

During the last oil crisis in 1973[1] and the subsequent energy crisis in 1979, energy was in the headlines, and oil prices more than doubled for a short period. For the next two decades, oil prices remained relatively stable, and, consequently, efforts at maximizing energy efficiency were pushed to the background.

In recent years, energy has resurfaced as a prime public policy,



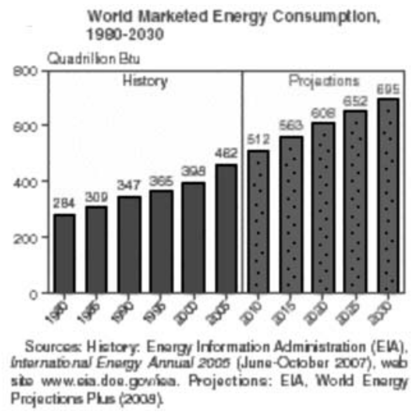


Figure 1. Crude Oil Prices 2005-2010 (proj.) and Global Energy Use 1900-2030 (proj.)

partly for reasons of national security and energy independence from the unstable Middle East, and partly because of global warming. The price of oil, although stabilized recently[2], is unlikely to continue its downward trend as global energy consumption continues to rise[3].

In this article, we will review who sets large-scale energy targets in the US, how well we are meeting them, and some ideas about how efforts to meet these targets could be aided by using building energy management systems and associated third party tools such as energy dashboards and fault-detection tools.

ENERGY TARGETS

In the US, energy targets relevant to the building and construction industry have been set by:

- The federal government, through executive order 13423, which mandates a reduction in energy use of 30 percent by 2015, relative to the baseline of the agency's energy use in 2003[4]. This includes roughly 3 billion square feet of building area.[5]

- The federal government, through the Energy Independence and Security Act of 2007 (EISA),[6,7] which sets new targets for equipment efficiencies and commercial buildings, and mandatory targets for federal buildings, that dovetail with executive order 13423 to reduce fossil fuel consumption by 55 percent in 2010, and by 100 percent by 2030[8].

- The federal government through DOE and US EPA, with the EnergyStar rating system for appliances and buildings.[9]

- The federal government, through the State Energy Program (SEP),[10] providing funding for energy efficiency projects in the commercial sector.

- Individual state governments, such as California,[11] which require new state buildings to be LEED-NC Silver certified and existing state buildings to be LEED-EB certified.

- LEED energy targets, which vary by certification[12] and provide points for beating local energy codes by a certain percentage.

- Local municipalities, which are beginning to require LEED certification (or certification very closely resembling the LEED system).[13,14,15,16]

While the federal standards are clearly stated, the State Energy Program does not have specific goals expressed in percentage improvements per year, nor does LEED have a straightforward key that translates a certain LEED rating into energy efficiency that is readily measurable.

This provides one of the first stumbling blocks in attempting large-scale assessments of energy efficiency improvements: the quantities to be measured are not clearly defined, nor are the means by which to measure them. In some cases, computer modeling in energy audits is substituted for measurements.

With any project, successful completion requires feedback on activities or sub-targets during the course of execution, with changes in course as required for staying on track.

This is where a key difficulty arises when dealing with energy. It is hard to quantify the actual performance of buildings, for a number of reasons, both technical and procedural:

- Energy consumption as measured by a utility does not necessarily reveal anything about the efficiency of a facility. Energy consumption is affected by occupancy (hours per day in operation), facility size (for energy use per sq ft), facility type (data centers will consume more than offices), and weather (hot years will see worse performance).

- Thus, metrics are required that allow the verification of energy performance in some uniform manner which does not introduce excessively complicated calculations but provides enough data to make sense of energy use in the context of measuring annual changes in energy efficiency.

- In the absence of agreement about a methodology for assessing building performance, it appears likely that no good feedback mechanism is in place to determine whether we are actually meeting the targets that have been set.

The author has found that conducting energy studies and projecting energy savings using energy modeling is an inherently inaccurate methodology. Instead, it is the author's opinion that the best approach for gauging success lies in measuring large numbers of buildings to generate statistically meaningful results. This requires some degree of automation and thus agreement about what to measure and how to measure it.

Performing such large-scale measurements would have the benefit of relieving policy makers from the burden of finding "correct" targets for individual building types and applications. Instead, the rating system would simply sort all building performance within a certain sector and show each building's performance relative to its peers, just like the EnergyStar rating system already does.[17] The current EnergyStar database contains about 7,000 buildings where performance has been evaluated.[18] This has the added benefit that, as better buildings emerge, they shift the average for all other players and continually update standards to goals that are realistic and improving over time.

Let us examine how well the attainment of energy targets is currently being measured to see if additional energies should be spent in this regard.

MEETING ENERGY TARGETS

How well are we meeting the energy targets set forth in the previous section?

Starting with federal government targets, the website of the Federal Energy Management Program (FEMP) contains annual reports on progress[19]. However, the latest such report[5] dates back to 2006, and it shows data between 2003 and 2006. The question arises as to where

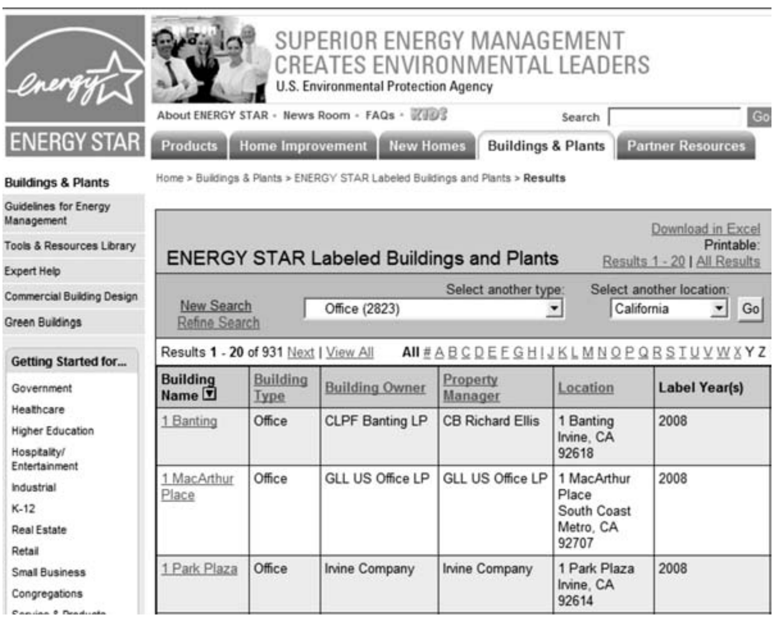


Figure 2. EnergyStar allows ranking of buildings online.

we stand now, in 2009, halfway along the execution path laid out in executive order 13423.

It is unclear how well energy efficiency efforts have worked since the 2006 measurement. In our experience, the initial energy savings measures totaling around 10-15 percent of facility use for existing buildings are relatively easily attained, and they are often classified as "low hanging fruit" because of their comparatively low implementation cost. However, reaching a savings of 30 percent is a more costly goal to achieve and, in some instances, cannot be achieved without drastically altering a building's systems.

Thus, a key to understanding how well energy efficiency efforts are being sustained would be recent data. It would not be surprising to see a relative flattening of the curves in Figure 3 as facilities go through their first improvement cycle, but either further improvements are deemed life cycle cost ineffective, or funds are simply unavailable.

On the other hand, it may also be very possible that improvements continue at a sustained rate—but reporting stopped in 2006, for reasons that are unclear.

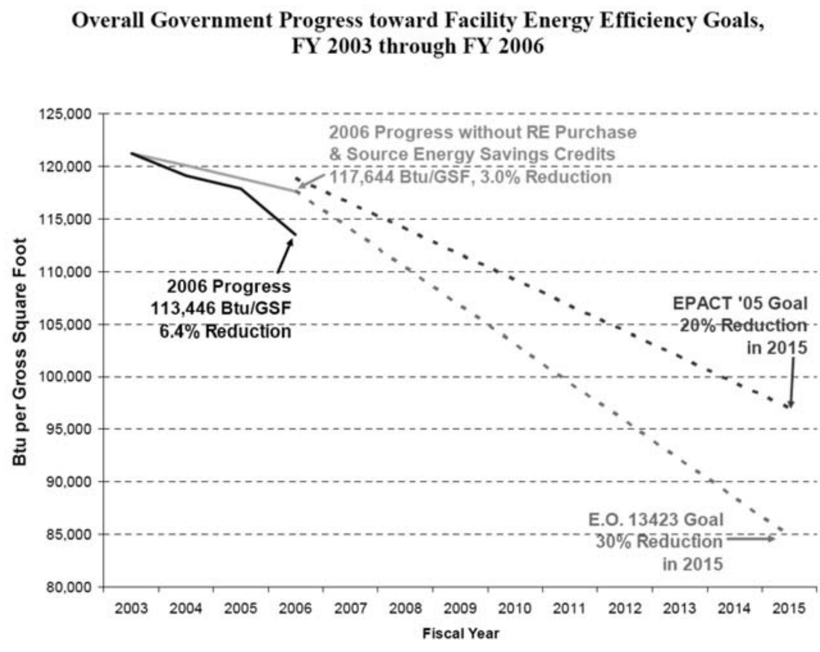


Figure 3. Federal Energy Management Program—latest annual report

Similarly, the State Energy Program (SEP) website shows no concrete numbers for an overall picture; this is not particularly surprising, since its focus is on supporting more localized improvement efforts with grants. The only reference to studying performance appears to be a report by DOE's Oak Ridge National Laboratory[20] that quantifies possible savings, based on 2002 data.

The US Green Building Council (USGBC), originator of the LEED rating system, commissioned a study on the effectiveness of the rating system that was executed by members of the New Buildings Institute (NBI).[21] It shows that, on average, buildings with various levels of LEED certification do appear to use less energy than the average found in the Commercial Buildings Energy Consumption Survey (CBECS)[22] by the Energy Information Administration (EIA), which includes about 5 million buildings with about 70 billion sq ft of space.

The results of the study are somewhat less conclusive when one considers two factors:

- The study compares 2006 building data for 121 LEED buildings with 2003 data for commercial buildings throughout the US. This comparison is inherently skewed, since more recent CBECS data

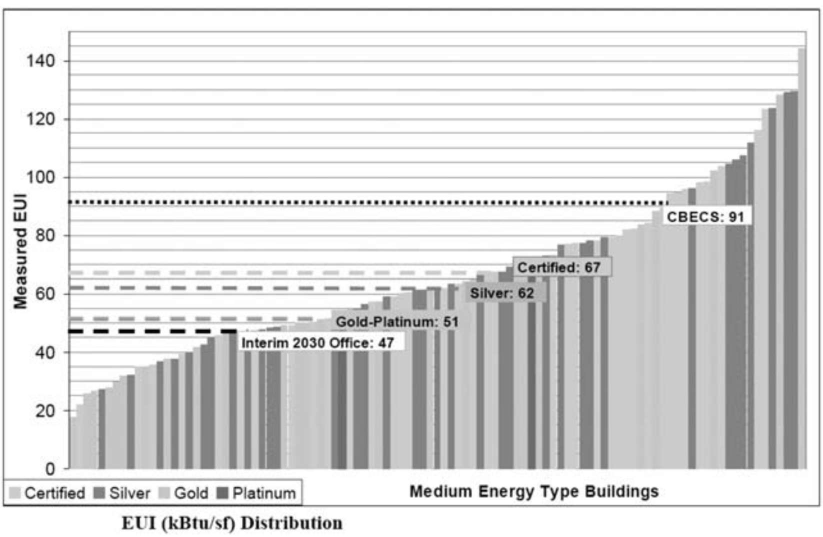
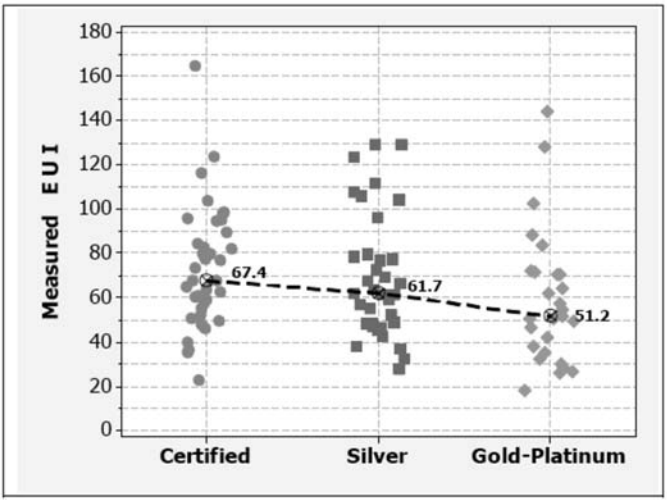
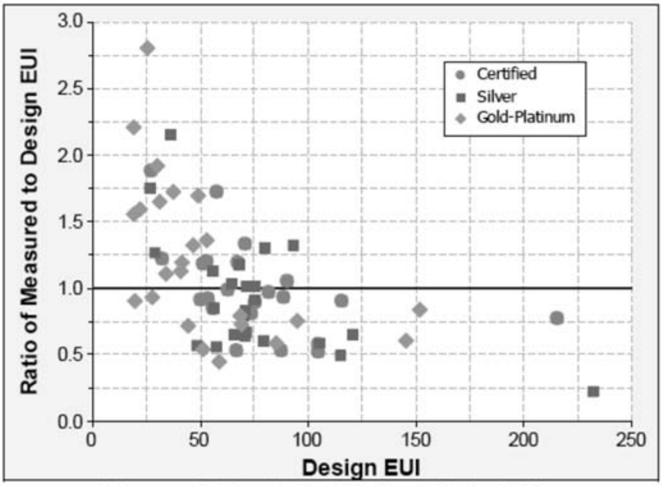


Figure 4. Comparison of EUIs from LEED certified buildings and CBECS average



Source: NBI 2008



Measured/Design Ratios Relative to Design EUI

Source: NBI 2008

Figure 5. Spread in EUI for certification levels, and difference between predicted and actual EUI

would hopefully show improvements as well, thanks to the focus on energy. In addition, 70 percent of the LEED projects included in the report were located in mild weather zones (ASHRAE climate zones 4 and 5), while CBECS includes very hot and very cold climate zones, which inherently show worse energy performance.

- The study shows a very wide spread in energy use for each LEED certification group and an equally wide spread in predicted and actual energy use.

In summary, it appears that we do not have a good system that allows us to track progress with respect to energy efficiency. As such, meeting the energy targets set by various agencies is made much more difficult.

MEASURING PROGRESS

What would be required to better measure progress? A near-instantaneous method of tracking energy use and relaying this information to all stakeholders through the internet would be a good way to improve our understanding of just how effective certain efforts are.

There are examples of systems with very similar technical requirements; the real estate tracking programs Zillow and Trulia have developed very easy-to-use interfaces, examples of which are shown in Figure 6. Using publicly available data, these companies compile statistical comparisons of real estate prices and map them out in colored charts to give users an instant understanding of conditions with a national or local framework.

A similar system could be used to map EUIs or agreed-upon metrics to show the success of energy savings measures. The underlying mathematics could of course easily be escalated, as Figure 7 shows; rather than just plotting real estate prices, the figure shows the percentage of homeowners who purchased between 2005 and 2008 and currently have negative equity.

A great deal more data have to be collected to allow this kind of analysis, but this does not appear to be insurmountable for a 4-year-old startup company.

Using this kind of technology, year-by-year changes in energy

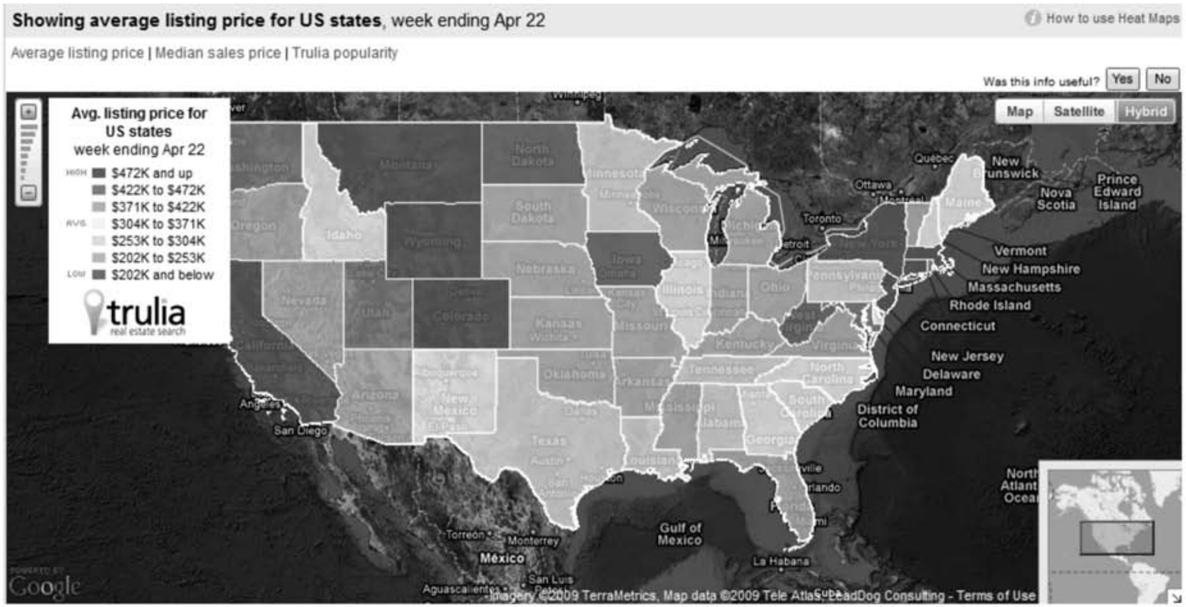


Figure 6. Average real estate prices per state

use could easily be brought into view and compared to dollars spent to obtain an idea of where to most efficiently allocate funds for energy rebate and incentive programs.

One key issue to determine before starting such a national energy database would be what data should be collected for comparison. Clearly, there would have to be an agreement between all stakeholders about what metrics should be produced at the building level for collection by (presumably) DOE.

The American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) currently has efforts underway to provide better information about building energy use and efficiency:

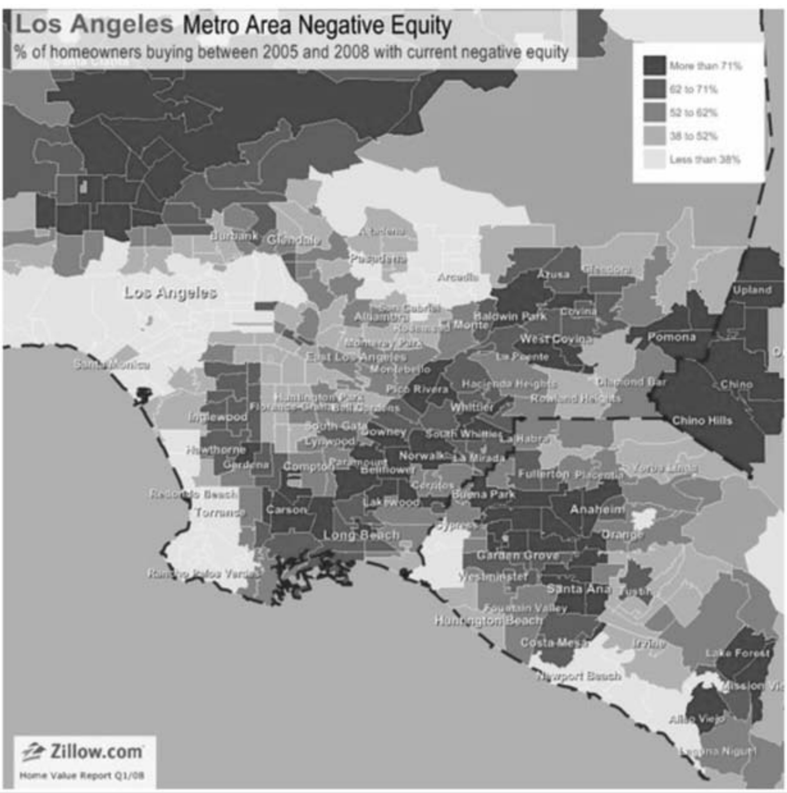


Figure 7. Percent of homeowners buying between 2005 and 2008 with current negative equity

- The ASHRAE building labeling committee[23]
- A Research work statement (1502-WS)[24] out for bid in fall 2009

These efforts will help create an understanding about the type of information that needs to be tracked. Energy management and control systems and third-party tools can play a vital role in this regard; once metrics are agreed upon, these systems can provide scalable solutions so that the results of energy measurements are updated automatically and in real time.

Utilities already collect energy consumption data, but they lack the additional information required to convert this information into usable metrics that address building efficiency. For example:

- Imagine that one of the metrics to be tracked was the energy use per occupied square foot per year for a building. The utility company would record the actual energy consumed, but the EMCS or third party software could report, through its occupancy status by floor or tenant, how this energy use translates into building efficiency.

- Using the web interfaces already available on most EMCS platforms and third-party dashboards, such information could then be exchanged on a regular basis with the server of a national database.

Some development would of course have to take place within EMCS platforms or third party dashboard applications to make such update mechanisms technically possible. However, the technical hurdles appear relatively small.

The larger issue would appear to be the motivation for a wide number of service providers to get together to produce such common output. Here we look again to the US DOE State Energy Program website[10] to find Figure 8, which is based on the results of an Oak Ridge National Laboratory report[25] on savings based on measures implemented in 2002.

If federal and state funding allocations could be improved by 10 percent, thanks to a better picture of what measures work and what measures do not, it would seem that substantial funding should be available for such an effort.

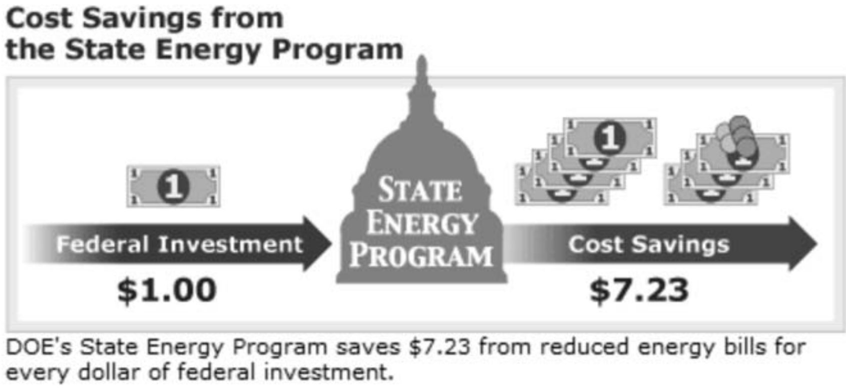


Figure 8. Funding results for 2002 State Energy projects

IMPROVING EFFICIENCY

With a better idea of where efficiency goals remain unmet, using the above mapping method, efforts could then be concentrated on the worst-performing buildings.

Implementing improvements in poorly performing facilities could potentially be accelerated by the availability of large-scale data. Current methods for assessing energy performance, such as federal guidelines[26,27] or ASHRAE energy audits,[28] which require life cycle cost analysis and energy modeling, are difficult to scale over millions of buildings. While LCC cannot be avoided entirely, it is the author's opinion that actual field data from implementation of, for example, demand-based reset strategies, could provide a better estimate of savings than energy modeling. With such an approach, a series of prescriptive measures based on feedback from thousands of actual projects could take the place of labor-intensive investigations and greatly improve the scalability of energy conservation measure (ECM) selection and implementation.

To limit the worst performers to a small number to begin with, the scalability of building systems could be improved in a number of other ways. Commissioning a building may often take six months or more. Such a period is hardly ever accounted for in construction planning, and consequently, most contractors have left the site, and retention moneys are paid while the commissioning agent's work is not yet completed. Significant improvements to scalability in this regard could be:

1. **The use of better and more standardized control sequences of operation**. The more energy efficiency we aim for, the more complicated the sequences of operation will become. In the author's experience, many design engineers and field installers are unaware of the latest available, and sometimes mandated, control mechanisms. Figure 9 shows an example user interface from the advanced VAV design guide.[29] Such user interfaces are required to verify whether complex control sequences are working, but that currently has to be specified on a case-by-case basis. For the example in question, demand-based pressure reset is actually a code requirement for many states using the International Energy Code (2006 IECC §503.4.2). Programs to support such sequences and related interfaces could be provided as integral library components within EMCS platforms. An ASHRAE research project (1455-RP) is currently underway to define such improved and standardized control sequences.[30]

2. **More uniform approaches to storing test data.** Commissioning a building requires a number of steps that recur on almost every project and yet have found little standardized support tools within EMCS platforms: test and balance (TAB) activities, pre-functional testing, and functional testing. The results of these tests could be stored directly in the EMCS itself (and in a few cases, are) so that the (typically) handwritten report from the installing contractor does not have to be transmitted back to his/her office for processing. The commissioning contractor often receives the typed report two to three months later, after which the contracting team has left, and at which point the rectification of problems is much harder because it requires a return to the site. Providing somewhat uniform approaches to storing test data for approval could greatly speed up commissioning and debugging efforts and lead to improved actual efficiency in buildings.

3. **Trend reviews**. To ascertain whether a building is working as intended at the end of commissioning activities, a trend review is often conducted. This involves collecting large volumes of data from the EMCS and analyzing these data—typically in third-party tools. Creating a common data format for exporting EMCS data from all platforms would allow a significant scaling of third-party tool development and accompanying actual performance assessments. There are efforts ongoing within ASHRAE to introduce such a data standard into BACnet.[31]

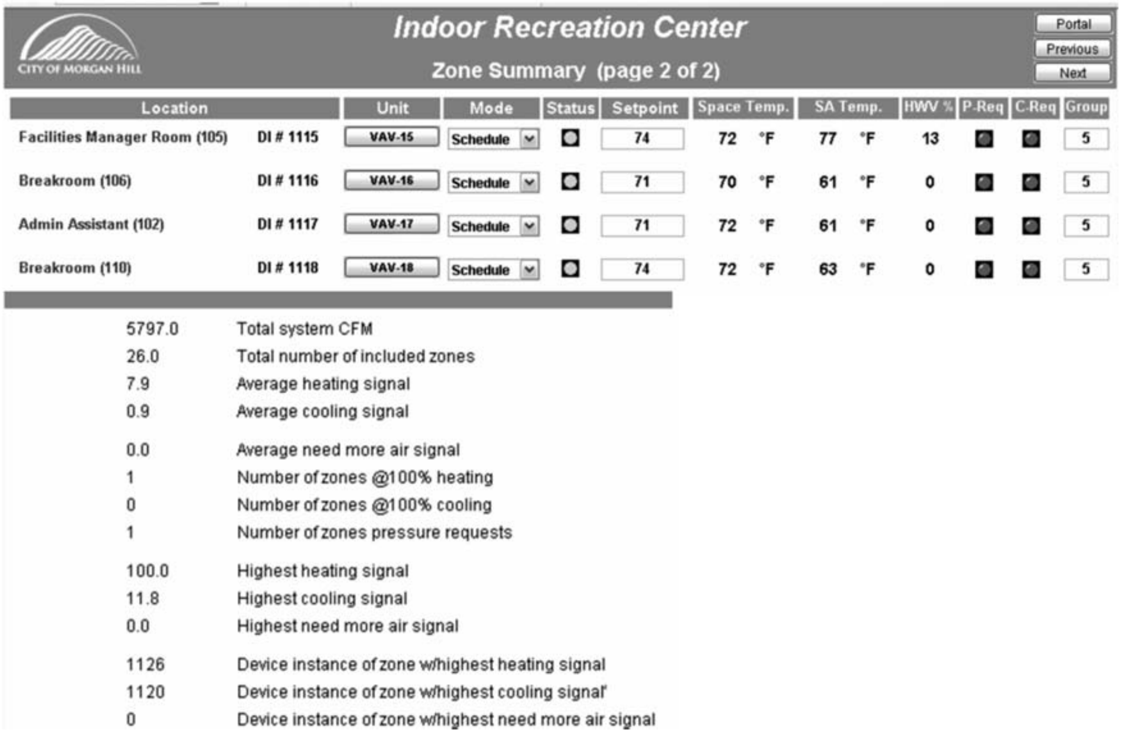


Figure 9. User interface to verify operation of complex but code-mandated control sequence

4. **Fault detection and diagnostics (FDD)**. There are ongoing efforts to provide tools, either by third-party vendors or within EMCS platforms, to automatically detect faults and indicate to building owners what corrective steps need to be taken. These results, too, could be transmitted to a real-time database so that the most common sources for building malfunctions (we know that airside economizer dampers will likely top this list but what else?) can be detected, and funding can be provided for better product development, product standards, and enforcement.

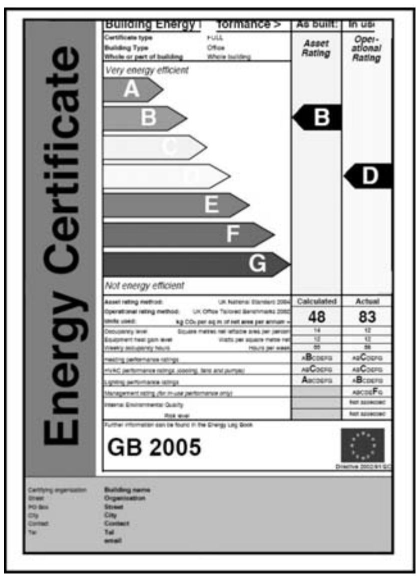
STANDARDS ENFORCEMENT

The technical requirements of improving individual building performance and the setting of equipment and performance standards are relatively easy to understand, even if they are difficult to implement in the real world.

But the success of looking at these tools stands and falls with the enforcement of standards and efficiency requirements.

Two examples illustrate this point:

1. The European Union countries have been working on defining building metrics for energy assessment for the last ten years, and they have developed a building labeling system[32] with certificates, seen at right. Producing such certificates has become mandatory.[33,34] Despite this, the number of buildings with online information is astonishingly small—the public energy performance labeling website[35] contains listings of roughly 20 buildings.



2. California has stringent energy code requirements,[36] described

in California's Title 24. As part of the 2005 code cycle, functional test forms were included that provide pre-formatted documents with checkboxes, to make functional testing for typical trouble components such as economizers more uniform and easy to execute. The example below shows a test form for small package units. Despite the introduction of this code in 2005, our office has yet to see a single project where the mandatory forms were completed. In many cases, contractors are unaware that such forms exist. When included on the front page of drawings, they are ignored, since they represent only a cost to the contractor, with all potential benefits going to the owner. Without enforcement by local authorities, these forms are ultimately meaningless.

The allocation of funding for enforcement by local authorities having jurisdiction (AHJ) thus appears as important as any of the other efforts described in this article, and this should be an integral part of devising any strategy aimed at improving energy performance on a large scale.

CONCLUSIONS

To meet the challenge of improving our national building energy consumption through improved efficiency, a large-scale approach is needed. In the author's view, some of the techniques currently employed for identifying and implementing energy improvements are not efficient, and a better approach would be the collection of performance data on a national scale in real time. These data could then be used to track progress, identify energy savings measures that work, and implement such measures, using a prescriptive approach in a much faster time frame than current methods allow.

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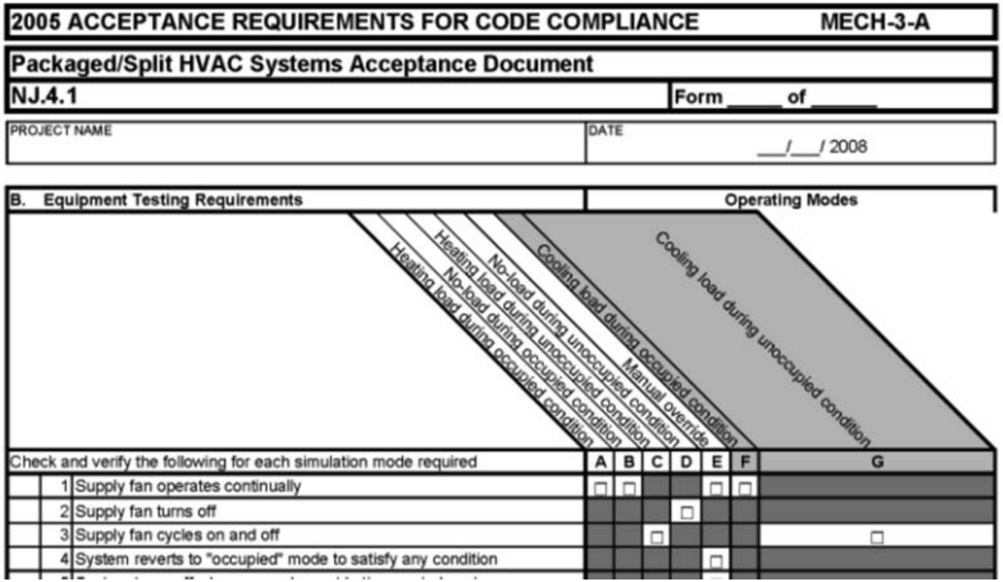

2005 ACCEPTANCE REQUIREMENTS FOR CODE COMPLIANCE **MECH-3-A**

Packaged/Split HVAC Systems Acceptance Document

NJ.4.1 **Form ____ of ____**

PROJECT NAME

DATE ___/___/ 2008

B. Equipment Testing Requirements **Operating Modes**

Check and verify the following for each simulation mode required	A: Heating load during occupied condition	B: No-load during occupied condition	C: Heating load during unoccupied condition	D: No-load during unoccupied condition	E: Manual override	F: Cooling load during occupied condition	G: Cooling load during unoccupied condition
1 Supply fan operates continually	☐	☐			☐	☐	
2 Supply fan turns off				☐			
3 Supply fan cycles on and off			☐				☐
4 System reverts to "occupied" mode to satisfy any condition					☐		

Figure 10. California Energy Code Equipment Test Form

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