Lawrence Berkeley National Laboratory
Recent Work

Title
Review of EPA Energy Efficiency Targets: A Case Study Analysis of Five EPA Buildings

Permalink
https://escholarship.org/uc/item/1ps390qw

Author
Kehrli, Tim

Publication Date
2006-03-23
Review of EPA Energy Efficiency Targets: A Case Study
Analysis of Five EPA Buildings

Report prepared for:
Bucky Green and Dan Amon
Sustainable Facilities Practices Branch
Facilities Management Services Division
U.S. Environmental Protection Agency

Report Authors:
Paul Mathew, Lawrence Berkeley National Laboratory
Tim Kehrli, TLK Consulting

Energy Modelers:
Eric Christensen, Econergy
Arvinder Dang, Syska Henessey
Fred Porter, Architectural Energy Corporation
Russ Taylor, Steven Winter Associates
Executive Summary

EPA’s current minimum requirements for new construction are: LEED Silver rating, design energy use 30% lower than ASHRAE 90.1-1999, and an EnergyStar score of 75. The purpose of the study documented in this report was to review these requirements in order to help determine if they should be modified. Five recent EPA projects - three office buildings and two labs – were studied. The energy performance of each facility was analyzed relative to different baselines, including ASHRAE 90.1-1999, ASHRAE 90.1-2004, the Labs21 modeling guidelines for laboratories, and EnergyStar for office buildings. The study showed that results varied widely for each of these baselines. Some of the key results of the analysis are:

- All the office buildings exceeded the ASHRAE 90.1-2004 baseline, although none of them reached the 30% target. One office building exceeded the 30% for regulated loads (i.e. excluding plug loads).
- All the office buildings scored higher than 75 on the EnergyStar rating, based on designed energy use.
- The energy savings calculation for laboratories varies widely depending on how the baseline is defined and interpreted, especially as it relates to fan power limitations, energy recovery and supplemental cooling. A strict interpretation of ASHRAE 90.1 results in negative savings for one laboratory and less than 10% savings in the other. Labs21 modeling guidelines address some of these issues and result in higher energy savings than the strict interpretation of ASHRAE 90.1.
- The energy savings percentages can be significantly impacted by modeling assumptions. The magnitude and direction of changes in the savings percentage is context dependent.

There is no “silver bullet” specification approach to ensure that EPA facilities will be designed and constructed to meet efficiency goals. In addition to the rating systems described above, the study also reviewed the Benchmark rating system developed by the New Buildings Institute. As such, each rating system has its strengths and limitations. EPA might consider a hybrid approach that captures the strengths of various rating systems. For instance:

- ASHRAE requirement: In office buildings, exceed ASHRAE 90.1-2004 by a 30% (regulated loads) and/or 20% total loads, using Appendix G of the standard. Laboratories should be modeled using the Labs21 guidelines. The percentage requirements should be revised downward for laboratory buildings.
- EnergyStar: Office buildings should be designed to achieve and EnergyStar score of 75 or higher.
- Additional requirements (which may be modified on a case-by-case basis) to address the gap between design intent and actual performance, as well as process loads. The NBI Benchmark includes several requirements along these lines, such as commissioning and certification; monitoring and trend-logging; electrical transformers; process loads. Sensitivity analysis and explicit documentation of modeling assumptions will also help to improve the quality of savings estimates.

Finally, it should be noted that any EPA requirements should be coordinated and aligned with the forthcoming EPACT guidance on efficiency targets for new construction.
1 Introduction

EPA’s current minimum requirements for new construction are: LEED Silver rating, design energy use 30% lower than ASHRAE 90.1-1999, and an EnergyStar score of 75. The purpose of this study is to review these requirements in order to help determine if they should be modified. Additionally, this project examines ways to strengthen modeling requirements to improve modeling consistency across different projects.

2 Approach

The approach to this analysis was to examine how the current requirements were applied to recent EPA projects. A total of five EPA projects - three office buildings and two labs – were studied, as shown below. While a study of these five buildings do not constitute a statistical sample to draw broad conclusions for all federal buildings, they nonetheless serve as an effective test case for EPA facilities.

Table 1 Buildings used in this study

<table>
<thead>
<tr>
<th>Facility</th>
<th>Building Type</th>
<th>Gross Area (sf)</th>
<th>Modeler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston Regional Office, Boston, MA</td>
<td>Office</td>
<td>633,032</td>
<td>Steven Winter Associates</td>
</tr>
<tr>
<td>Denver Regional Office, Denver, CO</td>
<td>Office</td>
<td>257,395</td>
<td>Syska Hennessey</td>
</tr>
<tr>
<td>Potomac Yards, Arlington, VA</td>
<td>Office</td>
<td>330,000</td>
<td>Econergy</td>
</tr>
<tr>
<td>Kansas City Science and Technology</td>
<td>Lab</td>
<td>71,955</td>
<td>Architectural Energy</td>
</tr>
<tr>
<td>Center, Kansas City, KS</td>
<td></td>
<td></td>
<td>Corporation</td>
</tr>
<tr>
<td>New England Regional Laboratory,</td>
<td>Lab</td>
<td>70,440</td>
<td>Architectural Energy</td>
</tr>
<tr>
<td>Chelmsford, MA</td>
<td></td>
<td></td>
<td>Corporation</td>
</tr>
</tbody>
</table>

Each of these facilities were modeled with DOE-2 during the design process, to evaluate compliance with the ASHRAE 90.1-1999 Energy Cost Budget (ECB) method. These were leveraged for this study, and the following analyses were conducted:

PART A: Comparison of different baselines

- Compare ASHRAE 90.1-1999 vs. 2004. For each facility, basecase and proposed design savings were calculated relative to ASHRAE 90.1-2004 and ASHRAE 90.1-1999.
- Examine correspondence between ASHRAE savings and EnergyStar scores. For the office buildings, the modeled energy use was used to obtain an EnergyStar score. Because these buildings have not yet been occupied, it was not possible to obtain EnergyStar scores with actual energy use.
- Compare Labs21 Modeling guidelines vs. ASHRAE 90.1-1999. For the laboratory facilities, basecase and proposed design savings were also calculated using the Labs21 modeling guidelines (Labs21 2005) – which are essentially a modification to ASHRAE 90.1-1999.

PART B: Impact of modeling assumptions

- Identify user-defined parameters that can significantly change base case and/or proposed design energy use and savings percentage using ASHRAE 90.1 (e.g. system type, fuel source, occupancy controls, schedules). This was done via group discussion with the modelers.
- Conduct parametric analysis on for significant user-defined parameters, in order to examine effect on calculated savings.
PART C: Review of New Buildings Institute’s Benchmark guidelines

- The purpose of this review is to explore how these guidelines can augment ASHRAE and EnergyStar requirements, especially as it relates to ensuring performance relative to design intent. This is not intended to be a comprehensive review, but rather to identify areas for further consideration.

3 Comparison of Baselines

3.1 Office Buildings

Table 2 and figure 1 summarize the results for the three office buildings, comparing the energy cost savings ($) relative to different baselines. Detailed results are provided in Appendices A-C.

Table 2: Energy cost ($) savings % for offices, calculated with different baselines.

<table>
<thead>
<tr>
<th>Facility</th>
<th>ASH-99 % save (reg loads)</th>
<th>ASH-99 % save (total)</th>
<th>ASH-04 % save (reg loads)</th>
<th>ASH-04 % save (total)</th>
<th>Energy Star Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>15%</td>
<td>12%</td>
<td>9%</td>
<td>7%</td>
<td>88</td>
</tr>
<tr>
<td>Denver</td>
<td>36%</td>
<td>26%</td>
<td>32%</td>
<td>23%</td>
<td>86</td>
</tr>
<tr>
<td>Potomac Yards</td>
<td>19%</td>
<td>14%</td>
<td>16%</td>
<td>12%</td>
<td>93</td>
</tr>
</tbody>
</table>

Some of the key observations from these results are:
- As expected, the % savings calculated based on regulated loads alone is more than the % savings calculated using total loads (i.e. including plug/process loads).
- The % savings calculated using ASHRAE 90.1-2004 are less than the % savings under ASHRAE 90.1-1999. This is primarily due to the 2004 version having more stringent baselines for lighting power density (1.3 W/sf in 1999, 1.0 W/sf in 2004).
- All the office buildings scored above 75 on the Energy Star scale and would therefore qualify for the EnergyStar label based on these simulated results. Note however, that the relative differences between the energy star scores do not correlate to the relative differences in energy savings.
between the ASHRAE savings. For instance, Denver has the highest savings, but the lowest EnergyStar score. This is discussed in more detail in section 3.

3.2 Laboratory Buildings

Table 3 and figure 2 summarize the results for the two laboratory buildings. In addition to the percentage savings relative to ASHRAE 1999, ASHRAE 2004, and Labs21 baselines, the results also include the percentage savings as calculated for LEED. In the case of Chelmsford, the calculation was based on ASHRAE 1989 (LEED 1.0). In the case of Kansas City, the calculation was based on ASHRAE 1999 (LEED 2.0), but with different interpretation of the standard, as discussed later.

Table 3: Energy cost ($) savings % for EPA laboratories, calculated with different baselines.

<table>
<thead>
<tr>
<th>Facility</th>
<th>ASH-99 % save (reg loads)</th>
<th>ASH-99 % save (total)</th>
<th>ASH-04 % save (reg loads)</th>
<th>ASH-04 % save (total)</th>
<th>Labs21 % save (total)</th>
<th>LEED % save (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chelmsford</td>
<td>-19%</td>
<td>-14%</td>
<td>-21%</td>
<td>-15%</td>
<td>13%</td>
<td>33%</td>
</tr>
<tr>
<td>Kansas City</td>
<td>9%</td>
<td>8%</td>
<td>8%</td>
<td>7%</td>
<td>16%</td>
<td>16%</td>
</tr>
</tbody>
</table>

Figure 2 Energy cost ($) savings % for the two EPA laboratories, calculated with different baselines.

The results for each laboratory are strongly influenced by their particular characteristics and the peculiarities of how the baselines are defined, as explained below.

Kansas City:
- As expected, the % savings calculated based on regulated loads alone is more than the % savings calculated using total loads (i.e. including plug/process loads) – however, the difference is fairly minor because the plug loads in this lab were only about 14% of total energy cost.
• Also as expected, the % savings calculated using ASHRAE 90.1-2004 are less than the % savings under ASHRAE 90.1-1999, although the difference is minor given that lighting is not a significant portion of laboratory energy use (lighting power allowances are the primary difference between the two versions).
• The savings relative to the Labs21 basecase are higher primarily because Labs21 almost doubles the fan power (hp/cfm) allowance. The ASHRAE fan power allowances are based on commercial buildings that have much lower static pressure than laboratories (e.g. 5” w.g. vs. 9” w.g.).
• Although LEED 2.0 uses ASHRAE 90.1-1999, the standard was interpreted differently for LEED evaluation. The LEED basecase model assumed a constant volume system with energy recovery. Furthermore, LEED allows the basecase and proposed models to have the same fan power.

Chelmsford:
• The significant observation is the anomalous results using ASHRAE. ASHRAE requires the basecase building to have a VAV system with 50% turndown or energy recovery with 50% total recovery. The minimum airflow has to be the same in the basecase and the proposed model. This lab has a supplemental cooling system in zones with high heat load. This energy saving feature allowed for a downsizing of the VAV system serving the labs, and as a result, this lab has a VAV system that turns down to only 55% of peak airflow i.e. if it did not have a supplemental cooling system, it would have had a larger VAV system, such that minimum airflow would be less than 50% of peak airflow. Ironically, since the system with supplemental cooling does not meet the 50% turndown, the basecase requires energy recovery in addition to the VAV system. This strict interpretation of ASHRAE, in combination with the fan power limitations in ASHRAE, results in a very aggressive basecase and overall negative savings.
• The savings relative to the Labs21 basecase are significantly different from the ASHRAE savings primarily due to two reasons:
  o Supplemental cooling is not included in the Labs21 basecase i.e. supplemental cooling is treated as an energy efficiency feature in the proposed model. As a result, the baseline VAV system meets the 50% turndown and does not additionally require energy recovery.
  o As discussed above, the Labs21 basecase allows for higher fan power allowances for laboratories, given their higher pressure drop relative to other commercial buildings.
• The LEED savings for this lab are based on LEED 1.0, which used the 1989 version of ASHRAE 90.1. As in the case of Kansas City, ASHRAE was interpreted differently for LEED evaluation.

Appendix D has a more detailed description of the differences between the basecases and how they were interpreted for this analysis.

3.3 Energy Use vs. Cost

The results above are based on total energy cost. Figure 3 compares the percentage savings using energy cost vs. site energy use vs. source energy use for the office buildings. The % cost savings includes the effect of demand charges, which is not captured in the % energy use savings. Furthermore, energy cost savings can be significantly impacted by the relative cost differences between electricity and natural gas. Because EPA has site energy use targets (e.g. in EPACT 2005) it is important to target, assess and report both energy cost savings and site energy use savings.
4 Sensitivity Analysis on Modeling Assumptions

The savings percentage calculated using the ASHRAE 90.1 ECB method is a function of how the basecase and proposed designs are defined and modeled. Furthermore, building energy modeling necessarily involves making assumptions on scores of parameters that are either undecided at the time of modeling (e.g. HVAC control sequences) or indeterminable (e.g. user behavior). Variations in these assumptions affect the simulated energy use, as well as the %savings calculated. While it is not possible to develop an exhaustive list of all the potential variations, a discussion among the four modelers for the five EPA facilities in this study identified the following major issues on the use of ASHRAE 90.1 ECB method:

- **System type:** The basecase and proposed design are required to have the same system type. Thus, the percentage savings will not necessarily reflect the savings of a high performance system type (e.g. ground source cooling) over a more conventional system type. (Note that this is not the case in Appendix G of the standard, which specifies a single basecase system for a given building size.)

- **Fuel source:** The basecase and proposed design are required to have the same fuel source. This would not, for example, show the benefits of fuel switching.

- **Standby losses:** The standard does not allow for the modeling of standby losses from gas systems.

- **Plug loads:** Plug load assumptions can vary widely and have a significant impact on energy use. High plug load assumptions will overestimate cooling energy use and the savings from efficient cooling systems, and low plug loads will overestimate heating energy use and the savings from efficient heating systems. A common problem is that closed perimeter offices are assumed to have the same plug load density as open office areas, when in reality they are lower.

- **Controls:** The standard does not provide specifications for all the control parameters that are modeled in DOE-2, requiring the modeler to make assumptions about several control parameters, such as supply air temperature reset control protocol.
Daylighting: The savings from daylight-based dimming of electrical lighting is significantly impacted by assumptions about lighting zone configuration, position of the sensors, and user behavioral effects.

In order to examine the impact of variations in these assumptions, several parametric energy simulations were conducted for each facility. Each variation was applied to both the basecase and proposed design cases. The variations are listed below:

1. A 50% increase in plug load power density.
2. A 50% decrease in plug load power density.
3. The use of natural gas vs. electricity as a heat source in offices and for humidification in labs.
4. Alternative approaches for supply air temperature reset: fixed (no reset) vs. based on zone-demand (using COOL-CONTROL = WARMEST in DOE-2) vs. scheduled by season (using COOL-CONTROL = SCHEDULED in DOE-2).

The results are indicated in figure 4 for the office buildings and the Kansas City laboratory. The figure shows that the savings percentage changes as a function of these variations (even though the variations are applied identically to the baseline and proposed models). For example, in Denver, a +/- 50% variation in the plug load assumption can change the %savings from 18% to 28%. The magnitude and direction of changes in the savings percentage is context dependent and this limited analysis does not allow for more specific conclusions. Rather, the purpose of this analysis was only to show that savings can be significantly impacted by modeling assumptions and that it is therefore important to do sensitivity analysis on major assumptions, and provide this information with the savings estimate.

![Sensitivity to Modeling Assumptions](image)

Figure 4. Sensitivity analysis on percentage cost savings relative to ASHRAE 90.1-2004, for different modeling assumptions. 'Reference' refers to the building as modeled.

The Energy Star rating system requires relatively few inputs, and therefore, has less sensitivity to input assumptions. For office buildings, the only inputs that may have some uncertainty are assumptions about the number of computers, and the working hours. Figure 5 shows the sensitivity to variations in the assumptions about the number of computers per person. Regardless of the specific value used to obtain a rating, it is important to ensure that the same assumption is used for the energy simulation model.
5 Disconnect Between Design Intent and Building Performance

It is often noted that a good design team can develop an energy efficient building, a good construction team can implement the design and a good operation team can deliver the targeted energy consumption. The reality is however that there is often a disconnect between design intent and actual performance.

One of the underlying objectives of this study was to explore ways to develop specifications for EPA facilities design and performance that minimize this predicament. The challenge however was to find a path for improvement other than adding to the current burden of design requirements. The design-performance disconnect has been documented by several researchers, including the New Buildings Institute (Johnson 2002). While there are several reasons for this, there are two key issues: The first is that design intent typically does not address plug and process loads (which are seen as outside the purview of building design). The second is that building performance is strongly influenced by how the building is commissioned and operated. Without standards in these two areas the actual building performance can vary greatly from modeled results.

The New Buildings Institute’s Benchmark (NBI 2005) is a standard that seeks to bridge the intent-performance gap by including requirements on control systems as well as performance verification during design, construction and operation. The Benchmark references LEED, ASHRAE 90.1, and EnergyStar. It also describes a structured process to meet the requirements of the Benchmark in an integrated manner – identifying steps to be taken at each stage of the design process, and the responsible parties for each step. While project schedule and budget constraints will require adaptations of this process for specific projects, it nevertheless is an approach superior to the business as usual construction process. Major renovation projects could also be approached with the same intent.
6 Discussion and Recommendations

6.1 Specifying a Target

There is no “silver bullet” specification approach to ensure that EPA facilities will be designed and constructed to meet efficiency goals. As such, each rating system has its strengths and limitations, as summarized below.

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE 90.1</td>
<td>“Apples-to-apples” comparison of design intent on key design features - effective for comparison of HVAC, lighting, envelope system alternatives. Baseline and proposed design are modeled in the same tool.</td>
<td>Does not account for poor controls, commissioning, construction and operation. No requirements for process loads. Sensitivity of results to explicit and implicit modeling assumptions.</td>
</tr>
<tr>
<td>EnergyStar</td>
<td>Provides a reality check and comparison against actual whole-building energy use data from a national sample.</td>
<td>Normalizes a limited number of variables - not pure “apples-to-apples” comparison between proposed design model and baseline measured data. Not available for laboratories.</td>
</tr>
</tbody>
</table>

Some of the specific factors to be considered are:

ASHRAE % reduction targets: EPACT 2005 requires 30% better than ASHRAE 2004, for all building types (including laboratories). ASHRAE 2004 Appendix G specifies that the calculation for percentage improvement has to take into account total loads (including process loads), not just regulated loads. Analysis of the above projects shows that this can be quite a challenge, especially for laboratories. But it may not be unreasonable for office buildings. (For instance, two-thirds of all office buildings certified under LEED have achieved the 30% target.)

Energy use vs. cost: ASHRAE requires that energy cost be used as the metric of compliance. EPACT and FMSD requires reporting of site energy use. Traditionally, energy cost serves as a reasonably good proxy for source energy. However, recent and future volatility in the natural gas and electricity markets may make this assumption invalid. It is suggested that EPA review percentage reduction results using both cost and site energy metrics. (This is a minimal additional burden since most energy modeling tools provide both metrics in their output.)
ASHRAE Appendix G vs. Section 11: An important consideration with regard to the use of ASHRAE 90.1-2004 is whether to use Appendix G rather than the section 11 for calculating savings. Section 11 is primarily intended for checking compliance, while appendix G was developed specifically for measuring performance against a benchmark. The advantages to using Appendix G include:

- It is specifically designed for quantifying improvements beyond the standard (In contrast, section 11 is designed for checking compliance).
- The baseline does not change with different system selections.
- It is required by LEED 2.2. Therefore, any project seeking LEED certification will already need to use Appendix G.

On the other hand, some of the disadvantages are that:

- It is not officially a part of the ASHRAE standard – it is an informational appendix. As a result, meeting the requirements of appendix G does not equate to compliance with the standard.
- It requires more modeling work that section 11.

On balance, it is recommended that EPA specify the use of Appendix G.

ASHRAE Labs21 Modeling Guidelines: For laboratory buildings, it is recommended that these guidelines be used, as they clarify and amend the ASHRAE standard to be more applicable to laboratory buildings, especially with regard to baseline systems and fan power limitations. Labs21 has released a draft version of the guidelines for use with ASHRAE 90.1 2004 Appendix G. It is anticipated that most of the key provisions will also be incorporated into the standard through “continuous maintenance” proposals.

EnergyStar targets: This analysis shows that requiring EnergyStar score of 75 or more for office buildings is reasonable and recommended. The design EnergyStar score also provides a reference point for subsequent annual tracking during the building commissioning and operation. Energy Star cannot be used for laboratory buildings.

6.2 Modeling assumptions

As the sensitivity analysis showed, the savings percentage can vary significantly based on modeling assumptions. As noted earlier, it is not possible to eliminate the uncertainty around savings estimates, due to the inherent uncertainty in energy modeling during design. However, it is important for decision-makers to have information on the range of uncertainty and its sources. Accordingly, it would be advisable for energy modeling scope of work to include:

- Identification and clear statement of modeling assumptions that significantly impact savings estimates, including (but not limited to):
  - Plug loads
  - Internal load schedules
  - Equipment operation schedules
  - Daylight modeling parameters (zone size, sensor location)
  - HVAC control parameters (supply air reset, static pressure reset, etc.)
- Sensitivity analysis on selected assumptions, to assess the range of savings uncertainty, similar to what was shown in this project. The range for each parameter can be determined on a case-by-case basis, via discussion between the modeler and the design team.

6.3 Conclusion

Taking into account the above discussion, EPA might consider a hybrid approach that captures the strengths of various rating systems. For instance:
• ASHRAE requirement: In office buildings, exceed ASHRAE 90.1-2004 by a 30% (regulated loads) and/or 20% total loads, using Appendix G of the standard. The percentage requirements should be revised downward for laboratory buildings.
• EnergyStar: Office buildings should be designed to achieve and EnergyStar score of 75 or higher.
• Additional requirements (which may be modified on a case-by-case basis) may include:
  o Commissioning and certification requirements (e.g. NBI Benchmark criteria 1.1, 1.2, 1.3, 4.1, 4.2, 4.3, 4.4)
  o Monitoring and Trend-logging (e.g. NBI Benchmark criteria 1.7)
  o Electrical transformers (e.g. NBI Benchmark criteria 1.8)
  o Process loads (e.g. NBI Benchmark criteria 1.13, 1.14)

Sensitivity analysis and explicit documentation of modeling assumptions will also help to improve the quality of savings estimates and reconciling major discrepancies between actual building performance and design estimates.

Finally, it should be noted that any EPA requirements should be coordinated and aligned with the forthcoming EPACT guidance on efficiency targets for new construction.

7 References


Appendices

Appendix A: Energy Analysis Report for Boston Regional Office
Appendix B: Energy Analysis Report for Denver Regional Office
Appendix C: Energy Analysis Report for Potomac Yards Office
Appendix D: Energy Savings vs. Multiple Baselines for Laboratories