Action-oriented Benchmarking: Concepts and Tools

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ABSTRACT

Most energy benchmarking tools provide static feedback on how one building compares to a larger set of loosely similar buildings, without providing information at the end-use level or on what can be done to reduce consumption, cost, or emissions. In this article—Part 1 of a two-part series—we describe an "action-oriented benchmarking" approach, which extends whole-building energy benchmarking to include analysis of system and component energy use metrics and features. Action-oriented benchmarking thereby allows users to generate more meaningful metrics and to identify, screen, and prioritize potential efficiency improvements. This opportunity assessment process can then be used to inform and optimize a full-scale audit or commissioning process. We introduce a new web-based action-oriented benchmarking system and associated software tool—*EnergyIQ*. The benchmarking methods, visualizations, and user interface design are informed by an end-user needs assessment survey and best-practice guidelines from ASHRAE.

INTRODUCTION

The anecdote "you can't manage what you can't measure" has become a cliché in the business world. Yet, when it comes to energy management, most building owners and operators lack even basic information as to how their property performs compared to their peers or best practices.

Energy benchmarking is an important tool for developing indices of energy performance and setting goals. Benchmarking metrics typically focus on whole-building energy use, represented with a unitless point system for rating, or absolute energy consumption and intensity indicators.

Uses of energy benchmarking as applied to buildings include:

- Determining how a building's energy use compares with that of others.
- Setting targets for improved performance and tracking progress/persistence.
- Facilitating assessment of property value and marketing rental properties.
- Gaining recognition for exemplary achievement.
- Identifying energy saving strategies.
- Providing reference points for commissioning and retro-commissioning.
- Improving energy demand forecasts (at a range of geographic scales).
- Providing feedback for design of better buildings (via design guidelines, standards, etc.).

The imperative for energy benchmarking is increasingly driven by federal and state policy initiatives. These include Federal Executive Orders mandating specific percentage reductions in overall energy intensity at federal facilities. Voluntary programs such as ENERGY STAR have been developed around benchmarking processes for buildings and equipment. Some building codes set benchmarks defined in terms of maximum allowed energy intensity levels. The governor of California issued Executive Order S-20-04 calling for development of a simple building energy benchmarking system. California Assembly Bill 549 also promotes benchmarking in the state.

Energy utilities are also evaluating the need for benchmarking tools to help them meet new aggressive utility-wide energy saving goals. California Assembly Bill 1103* requires electric or gas utilities to maintain energy consumption data for non-residential buildings in a format that is compatible for uploading to the United States Environmental Protection Agency's (EPA's) Energy Star Portfolio Manager program. Effective January 1, 2009, the utilities, on customer request, must upload all of the data for a building to the Energy Star Portfolio Manager. Effective January 1, 2010, non-residential building owners must disclose to prospective buyers and lenders the EPA's Energy Star Portfolio Manager data and scores for a building that is being sold, leased, financed, or refinanced.

*Now Public Resources Code Section 25402.10.

One review identified 47 protocols for benchmarking non-residential buildings and 31 that applied to residences.[1] However, most currently available benchmarking tools provide static feedback on how one building compares to a larger set of similar buildings, without end-use detail or information on what can be done to reduce energy use. This article introduces the notion of "action-oriented" benchmarking, which goes beyond the basic benchmarking methodologies by providing guidance on specific actions that can be taken to improve performance. A companion article outlines the detailed methodologies that we have developed.[2]

DASHBOARDS & ACTION-ORIENTED BENCHMARKING

The use of web-based information "dashboards" has come into vogue in all industries as a means of gaining greater insight into the effectiveness of business operations. Forrester reviewed the state of the art, including surveys of 22 early-adopter companies that were using computer-based information dashboards.[3] They found that these systems were often "tentative and not linked to business processes" and contained "passive displays meant for executive eyes only." If dashboards aren't connected to the people who "own" the processes they are evaluating, then the information does not become actionable. A metric that does not fit the need is of little value, and can even be counterproductive.[4] While there were no energy applications among those evaluated, it is safe to say that these same shortcomings apply to most existing energy benchmarking practices. Forrester urges that benchmarking methods be allowed to evolve, in part by allowing process owners to own the metrics they are using, and be able to refine them as needs change or new insight is gained as to how to correlate metrics to the root causes of problems.

Benchmarking is best viewed as an element of an integrated process for improving the energy performance of buildings. This process can be said to begin with design intent, progressing to occupancy and operation, and ultimately to repurposing or decommissioning a building. Action-oriented benchmarking is intrinsically more in-depth than conventional whole-building benchmarking, essentially forming a bridge between full-fledged simulation (for design) or energy audits (for retrofit), as shown in Figure 1. An action-oriented benchmarking process ideally interoperates with other aspects of building energy management, particularly commissioning and retro-commissioning, where results can help identify defi-

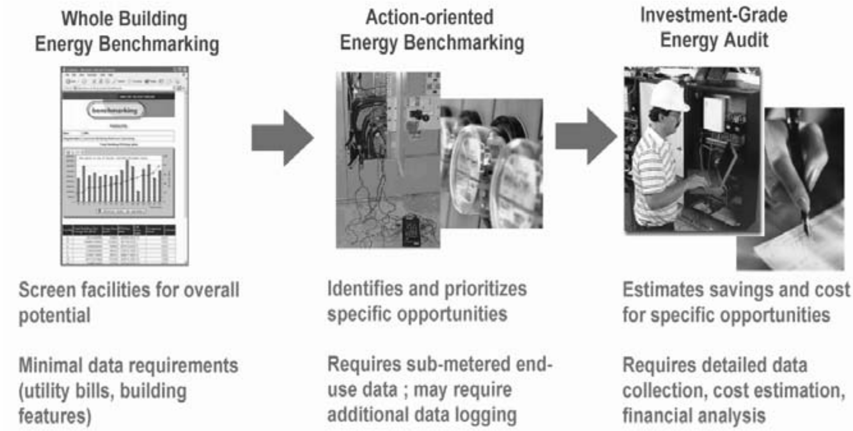


Figure 1. Action-oriented benchmarking in the context of conventional benchmarking and energy audits.

ciencies and suggest where interventions are merited.

In isolation, conventional energy benchmarking can inspire action but provides no practical guidance. Action-oriented benchmarking enables users to identify potential energy-efficiency options and prioritize areas for more detailed analysis and full-scale audits. This represents a means of opportunity assessment not afforded by conventional benchmarking. However, the choice of metric itself often dictates the general message conveyed and thus care should be taken to use appropriate metrics. For example, simply calculating miles-per-gallon as a transportation metric would always suggest that a motorcycle is the superior form of transportation. This could be impractical, especially in the case of overseas travel! Excluding load factors could make a bus look superior to a car, which may not be the case if ridership is poor in the bus and many passengers are in the car.

Relevant metrics are a central element of action-oriented benchmarking. Some users are motivated by traditional engineering metrics (e.g. energy per unit of floor area), while others find more meaning in metrics of cost or energy-related pollution released or avoided.

User-defined filters such as location or building type can make the results more actionable. An action-oriented process must offer cross-sectional analyses (e.g. for static comparisons to other buildings) as well as longitudinal (for tracking performance over time). Overlays of targets are a natural method for helping to define targets and gauging progress.

Granularity of analysis is also integral to the action-inducing value. High-level metrics, e.g. at the whole-building level, may suffice for some users. However, in other cases more detailed metrics are essential. This is especially the case if benchmark outcomes are to be used to infer specific measures that could be taken. This is rarely done in existing benchmarking tools, although examples do exist, such as the correlation of the type of air-handling systems with energy use in cleanroom benchmarking.[5]

TARGET AUDIENCES AND THEIR EXPECTATIONS

To gain insight into the features that potential users desire in an action-oriented benchmarking tool for energy use in buildings, we distributed a survey to 500 stakeholders around the United States. The response rate of 19 percent is considered quite good for surveys of this type, and the 95 respondents collectively influence 554 million square feet of building floor area (either as occupants or service providers). The key results are as follows:

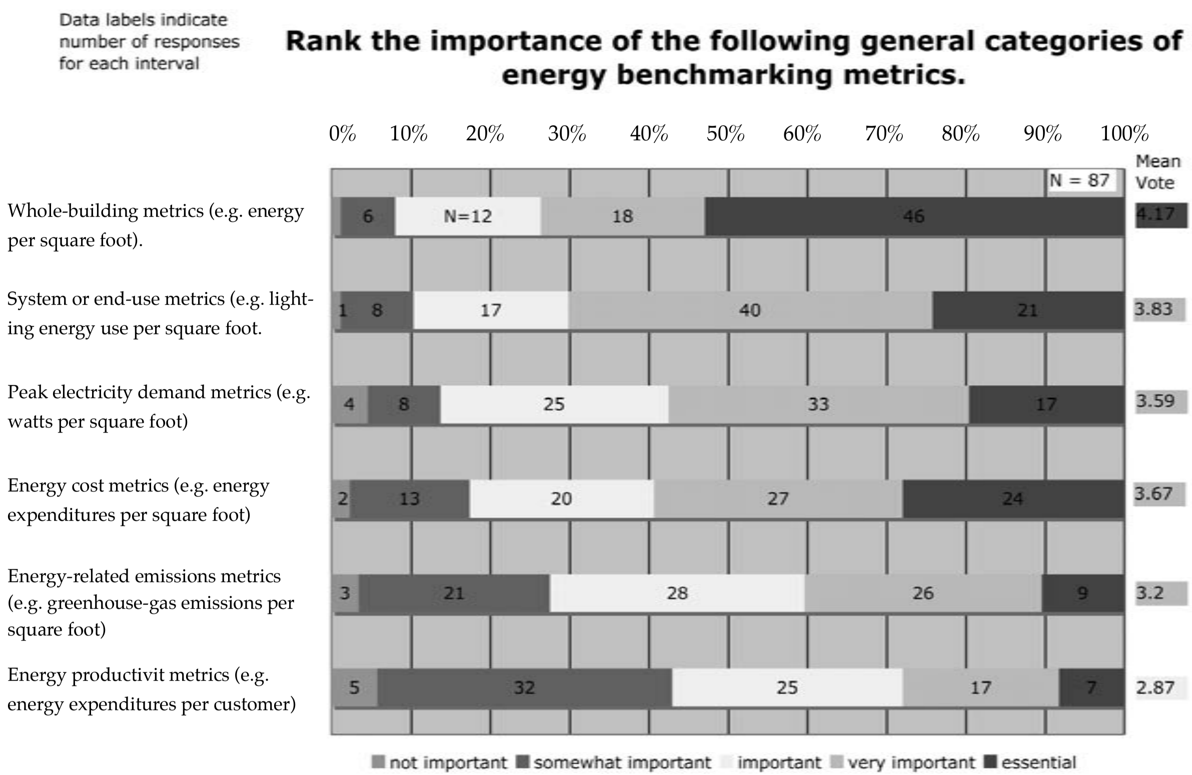
- 73 percent of respondents currently utilize some sort of energy benchmarking process, and apply it to a very wide range of building types.

- One in five respondents currently conduct some form of non-energy benchmarking (e.g. sales per employee), which suggests an opportunity to add value by enabling a benchmarking tool to utilize the same normalization factors.

- The three main reasons given for buildings' energy benchmarking were identifying energy efficiency opportunities, prioritizing investments, and making comparisons to other facilities. A quarter of respondents provided additional reasons, such as verifying energy savings, tracking persistence of savings, and making the business case for efficiency investments.

- Users assigned particularly high importance to six types of metrics: whole-building, end-use, peak power, energy cost, emissions, and productivity (e.g. energy cost per customer) (Figure 2).

Figure 2. Rank the importance of the following general categories of energy benchmarking metrics.



- Users ranked the value of various features and functions of a hypothetical benchmarking tool (Figure 3). Equal (high) importance was placed on applicability to new versus existing buildings and cross-sectional versus longitudinal benchmarking. The ability to import data from other sources was also assigned a high importance. Users desired to be able to include other users' benchmarking results in the peer groups to which they compare themselves.

- Respondents are willing to assemble and enter a range of data into an action-oriented benchmarking tool, including annual and monthly consumption as well as facility or equipment characteristics.

- Respondents fell into two cohorts with respect to the time they would be willing to spend using the tool. One group centered on the 0- 60-minute range while the other in the vicinity of 120 minutes or more. This pattern held across all user types (e.g. owners, tenants, service providers) (Figure 4).

- Virtually all respondents desired both graphical and tabular outputs. Only 7 percent wanted graphics only and only 1 percent wanted tables only.

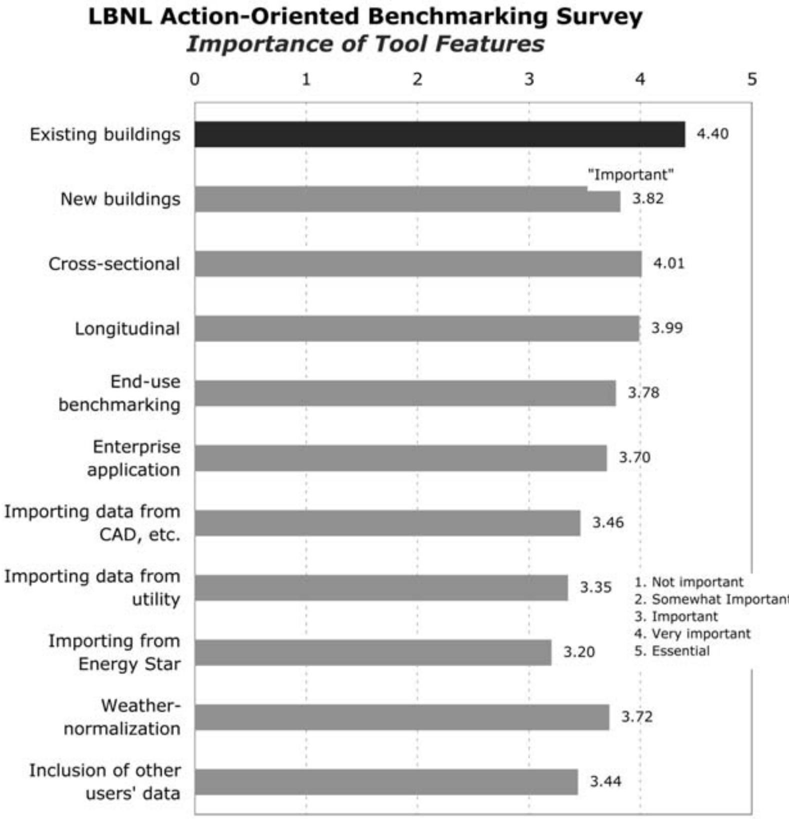
The work of ASHRAE Technical Research Project 1286 offers another assessment of best practices for energy benchmarking tool design. The project picked some of the tools they believed to be most promising and evaluated them against a number of criteria.

Among their findings:

> "The consumption-based protocols fail in providing good design guidance and feedback during the design process. The point-based protocols more directly affect design but require too much effort and expenditure for smaller commercial buildings that make up a very large fraction of the building stock."

Their findings seemed to indicate significant room for improvement, and a void yet to be filled by tools that could be used to assess efficiency opportunities and recommend "actions." The ASHRAE project identified a number of features and criteria that they believe should be elements of ideal benchmarking protocols (Table 1).[6]

Figure 3. LBNL Action-oriented Benchmarking Survey



PROTOTYPE SOFTWARE TOOL

In response to policy mandates, recent research at LBNL has developed a new action-oriented benchmarking system for non-residential buildings that incorporates a building-stock energy database of unprecedented quality, and emerging technology for web-based interfaces. Designed as a web service, any number of third parties can design their own user interfaces to tap the benchmarking methods and visualizations.

The first such interface, called *EnergyIQ*,[7] is designed to meet the user needs identified in the above-mentioned survey and ASHRAE TRP-1286 best practices protocol. Initially designed for California, the tool will ultimately accommodate buildings throughout the United States and per-

Figure 4. LBNL Action-oriented Benchmarking Survey
Willingness to Spend Time Gathering/Entering Data

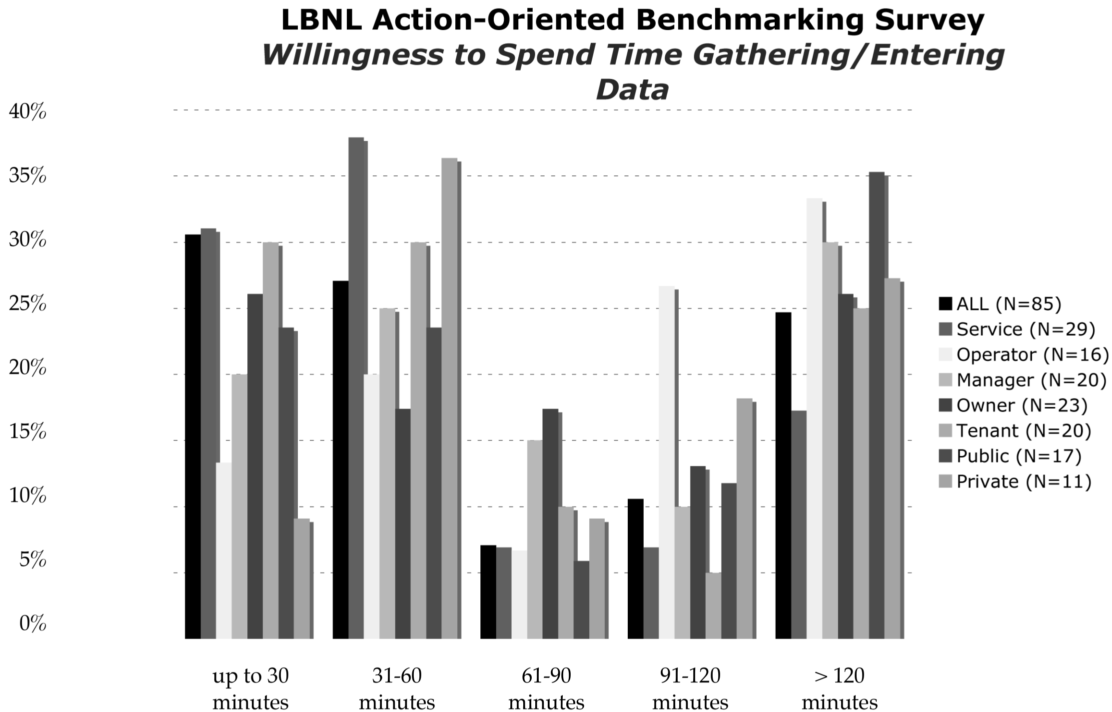


Table 1. Condensed summary of ASHRAE TRP-1286 best practice energy benchmarking tool design.

Focus on energy (vs. other resources)*	Provide weather normalization to allow for multi-year trending*
Emphasis on ease-of-use for non-technical building owners and operators*	Include recommendations*
Adopt a clear goal during tool development*	Limit to one input page; one result page*
Use empirical building survey data to define peer groups*	Provide user accounts with saved data*
Make it easy to update and add new data*	All major browsers supported*
Distinguish among building types*	Portfolio option for multiple buildings*
Use multiple regression plus "smoothing" *	Optional batch upload (FTP, etc.)*
Account for location/climate dependency*	Ability to combine multiple buildings*
Publicly document the rating method*	Utility data; upload*
Tool should be web-based with minimal inputs, e.g. monthly consumption, building type, floor area, location*	Link to utility program information*
Use a scale from 0 to 100 percent to bin results of peer group	Provide on-line "how-to-use" training*
Provide simple graphical output, like appliance labels*	Longitudinal benchmarking over time*
Use histograms for deeper (optional) analysis*	Can be statically integrated into utility websites*
Available at no cost to users*	Give additional points for "environmental criteria"
Link to simulation-based design compliance with ASHRAE standard	Certification program, based on tool
Limit rating to energy, as opposed to comprehensive environmental indicators*	Consistent floor-area definition*
Include CO_2 emissions*	

* Included in *EnergyIQ*

haps beyond. The technical methods are described in a companion article.[8] *EnergyIQ* represents a major advancement beyond LBNL's previous *CalArch* tool, which provided web-based whole-building benchmarking based upon an earlier version of the CEUS survey.[9]

To maximize ease of use and minimize distribution costs, problems with version control, platform dependencies, and cost of maintenance and updates, the tool is built as a web-based application (as opposed to a disk-based implementation). The platform provides a web service allowing qualified third parties to develop customized user interfaces.

The California End Use Survey (CEUS)[10] provides the initial peer-group data that underly the benchmarking process for *EnergyIQ*. CEUS is a highly detailed survey of approximately 2800 non-residential premises across California, based on a stratified random sampling across utility regions, climate zones, building types, and building size. In contrast to surveys relying on self-reporting, CEUS employed on-site surveys of building characteristics and monthly utility billing data. Short-term data logging and/or interval metering was performed at some sites. Energy intensities are derived from calibrated simulations, based on characteristics collected at the sites.

Figure 5 shows the single-screen user interface for benchmarking, and the resulting opportunity assessment and listing of candidate actions. The user-selectable chart types ("Views") include histograms, sorted bar charts, range bars, scatter diagrams, and pie charts.

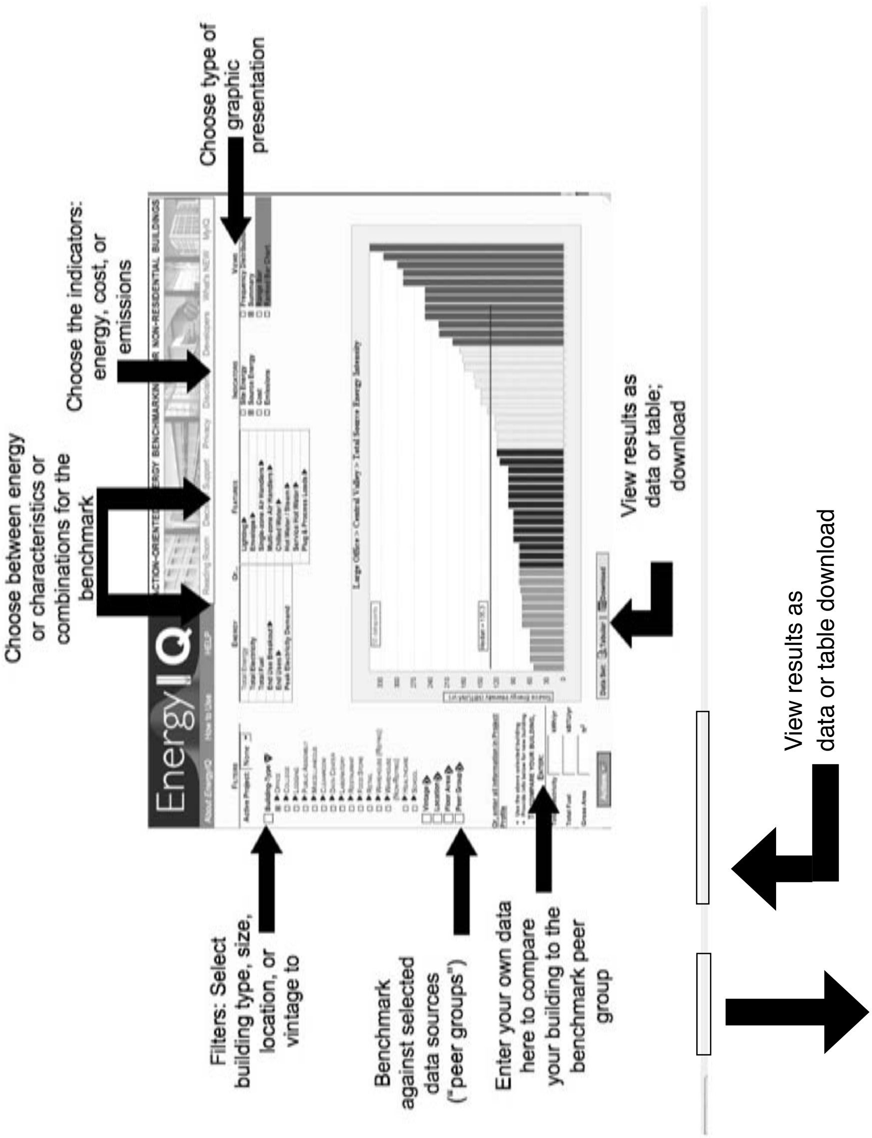
Several factors distinguish *EnergyIQ* from most other benchmarking tools.

End-use Benchmarking

The CEUS data are of unprecedented quality and detail. This enables a higher level of granularity in the benchmarking, ranging from campuses, to buildings, to systems, and to components.

Features Benchmarking

Most benchmarking methods focus strictly on using whole-building energy use to develop figures of merit. *EnergyIQ* accepts end-use energy data and also employs what we refer to as "features benchmarking." The premise is that there is value in benchmarking the presence or absence of certain features in a binary or qualitative fashion. Features benchmarking can also be based on equipment efficiencies (e.g. kW/ton) or product categories (e.g. types of lighting control), where data are available. With this


Choose between energy or characteristics or combinations for the benchmark
Choose the indicators: energy, cost, or emissions
Choose type of graphic presentation
EnergyIQ
View results as data or table; download
Filters: Select building type, size, location, or vintage to
Benchmark against selected data sources ("peer groups")
Enter your own data here to compare your building to the benchmark peer group
View results as data or table download

Based on user's buidling description,, a series of potential opportunities and "actions" are identified.

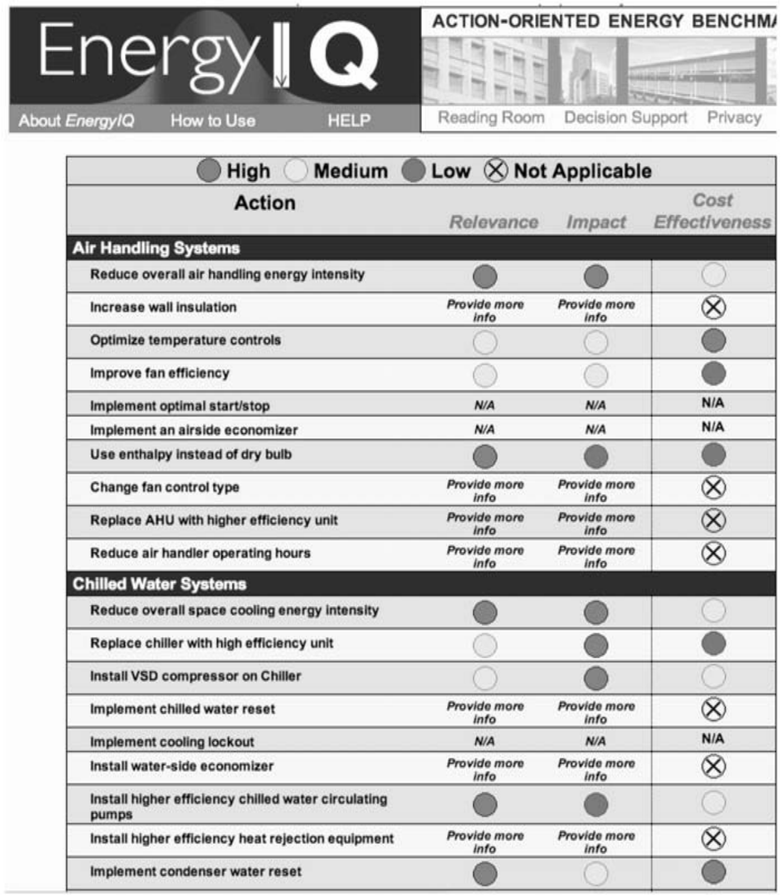


Figure 5. Screenshot of *EnergyIQ* benchmarking interface

information, correlations between features and energy intensities are used to help identify promising actions.

Visual Browsing and Selective Benchmarking

EnergyIQ speeds the user's path to useful results by allowing the user to visually browse a wide variety of metrics and visualizations generated dynamically based on the peer-group data via the web interface. For any view, the user has the option to enter the data necessary to map their own building onto that view. This contributes to the "action-oriented" philosophy of the tool requiring the user to enter only the data necessary to get the analysis they seek and metrics that have meaning for their particular situation.

Customized Peer Groups via User-driven Database Filters

Users always immediately receive results when they enter such data. The user can filter the data at any point by building type (62 options), location, vintage, floor area, and/or size. The user can describe portfolios of buildings and evaluate them individually or in aggregate. The tool accommodates databases in addition to CEUS, and the user has the option to include them as peer groups (as well as the results from other users of the tool) against which to compare their own buildings.

An Array of Display Options

EnergyIQ allows users to specify metrics of their choice, in terms of energy quantities, costs, or greenhouse-gas emissions. Energy-related views and metrics include total energy use, electricity, or fuel, at the whole-building and end-use level. Peak demand is also an optional metric, and one not typically included in benchmarking tools. A diversity of characteristics can be viewed, such as lighting type, HVAC equipment, and plug loads. Four general categories of graphical presentation are used: simple summaries such as tables, frequency distributions (quartiles, ranked, histogram, or scatter diagrams), and conventional bar charts visualizing an indicator such as equipment efficiencies.

Actions

Actions are generated based on a predefined deductive logic keyed to energy-use data as well as building features. The outputs are organized into three categories: the likely relevance or "fit" of a particular energy saving measure, significance of potential savings, and cost-effectiveness.

In the initial version of *EnergyIQ*, these results are largely qualitative (indicated on a scale of 1-5). Future versions may include simulation-based analyses that allow for quantitative evaluation of potential actions.

THE LIMITS OF ACTION-ORIENTED BENCHMARKING

As noted above, action-oriented benchmarking occurs in a broader context of understanding and managing building energy performance. While more dynamic and detailed than conventional energy benchmarking, action-oriented approaches are not a substitute for full-fledged energy audits of existing buildings or true simulation for new construction or retrofit. Action-oriented benchmarking does, however, provide a quick and low-cost screening process that can flag potential improvements or realistic targets.

As with most energy-management methods, there is often a gap between idealized best practices and what is practical or achievable given real-world constraints. For action-oriented benchmarking, this is particularly true. For maximum value, tool developers must have in-depth data on the building stock of interest to user audiences. This implies geographic diversity, many types of buildings, and extensive end-use energy data plus physical characteristics. The CEUS survey has proven to be an invaluable asset in these respects, although data gaps impose limitations.

On the user side, time and data are often limiting resources. Tools that require highly detailed input data and/or expertise present barriers to some users. The layered approach of *EnergyIQ* is intended to minimize the barrier of time availability. Users receive progressively more specific results, beginning with the most basic of data entry. Recommended actions become more detailed and relevant as the user chooses to provide increasing levels of detail about their building. Properly collecting and quality-controlling user-entered data is another requirement.

CONCLUSION AND OUTLOOK

Increasing energy prices, along with rising concern about climate change and energy security, are serving to elevate the interest in implementing energy-efficiency improvements in non-residential buildings. Benchmarking—particularly if action-oriented—is integral to the process of identifying opportunities and motivating decision-makers to implement measures that improve the energy performance of buildings. *EnergyIQ* represents a new generation of tools for increasing the role of benchmarking in this broader process.

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