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Publication Date

2004-05-26

Rating Energy Efficiency and Sustainability in Laboratories: Results and Lessons from the Labs21 Program

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ABSTRACT

Laboratories are very energy intensive, with significant opportunities for improved efficiency. However, their inherent complexity and variety makes benchmarking of their energy and environmental performance a unique and challenging task. Furthermore, laboratories have a myriad of health and safety requirements that significantly affect energy use, adding complexity to their benchmarking.

The Labs21 program, a joint program of the US EPA and US DOE, has developed two resources specifically for assessing laboratory energy and environmental performance:

- An energy benchmarking tool – which allows users to compare laboratories using a standard set of building and system level energy use metrics.
- The Environmental Performance Criteria (EPC) – a point-based rating system that builds on the LEED™ green building rating system, designed to score overall environmental performance.

In this paper, for each of these tools we present the underlying methodology and results from their use. For the benchmarking tool, we contrast our approach, which includes a simulation model-based component, with those used for other building types. We also present selected results from data collection and analysis of about 40 private and public sector laboratory facilities. In the case of the EPC, we describe variations from the LEED standard, focusing on the energy credits. Finally, using laboratories as a case in point, we discuss lessons learned that can be applied to the development of similar tools for other building types that have complex requirements impacting energy and environmental performance.

Energy Benchmarking

Why Benchmark Laboratories?

Energy benchmarking has been effectively used for comparing the energy use of offices, schools and other commercial facilities, most notably in the EnergyStar™ program. However, there have been limited efforts thus far to benchmark laboratory facilities, and no national efforts akin to EnergyStar™. This is partly due to the fact that laboratories constitute a fairly small part of total U.S. building energy use, and have not attracted the attention of national programs such as EnergyStar™. However, laboratory facilities are highly energy intensive, are a growing segment of the building sector, and have significant opportunities for energy efficiency. Owners and operators know their buildings are expensive to operate, but are often not able to tell how good or poor they are in terms of energy use. Consequently, they can benefit from energy benchmarking during design, commissioning, and operation.

With strong urging from the laboratory community, the Laboratories for the 21st Century ("Labs21") program sought to address this need by launching a laboratory benchmarking project. The mission of the Labs21 program, sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy, is to improve the energy and environmental performance of the nation's laboratories (see http://www.labs21century.gov). Accordingly, the primary motivation to develop energy benchmarking in laboratories is to identify best practices related to energy efficiency [Sartor et al. 2000].

Benchmarking Metrics and Methods

In principle, building energy benchmarking simply involves selecting an appropriate metric of interest and comparing buildings using this metric, after normalizing for parameters such as weather.

Labs21 gathered a group of laboratory designers, engineers, and operators to collectively develop a set of metrics that address both energy use (e.g. kWh/sq.ft.) and system efficiency (e.g. W/cfm). It is very easy to conceptualize a comprehensive set of metrics that would have such onerous data collection requirements so as to be of little practical value (in the first iteration, this group developed over 100 metrics). Therefore, the goal was to develop a more limited set of key metrics that allow for effective assessment of energy efficiency, without unduly burdensome data collection requirements. Table 1 shows this set of metrics, which includes several system level metrics in addition to whole building metrics. Table 2 shows the key normalizing parameters for laboratories.

Table 1. Standard Set of Laboratory Energy Use and Efficiency Metrics

System	Energy use metrics	System/load efficiency metrics
Whole Building	kWh/sf-yr (electric) BTU/sf-yr (site) BTU/sf-yr (source) Utility $/sf-yr	Peak W/sf Energy Effectiveness Ratio (Ideal/Actual)
Ventilation	kWh/sf-yr	Peak W/cfm Peak cfm/sf (lab) Avg cfm/peak cfm
Cooling	kWh/sf-yr	Peak W/sf Peak sf/ton
Heating	BTU/sf-yr	
Lighting	KWh/sf-yr	Peak W/sf
Process equipment	KWh/sf-yr	Peak W/sf

The core of the methodological choices and issues in benchmarking pertain to the approach used to normalize the value of the metric, in order to obtain meaningful "apples-to-apples" comparisons. Generally, there is a correlation between the rigor and reliability of the benchmarking, and the burden of data collection and accuracy requirements. This is invariably a challenge because most buildings are not sub-metered and monitored at the level desirable for benchmarking. But depending on the benchmarking application, various levels of benchmarking may be defined, as shown in Table 3. This corresponds to a hierarchical benchmarking approach [Sartor et al. 2000]. Note that for certain applications, simple data filtering (i.e. generating metrics from a subset of the data, based on certain criteria) can be a crude but effective alternative or supplement to more rigorous normalization approaches such as regression analysis or simulation model-based benchmarking (which is discussed in the next section). Normalization is most critical for whole building and system level energy use metrics. On the other hand, certain system level efficiency metrics such as lighting peak W/sf or ventilation W/cfm can be effectively used even without any normalization.

Table 2. Key Normalizing Parameters for Laboratories

Parameter	**Notes**
Gross area	Total area of conditioned spaces (laboratory and non-laboratory)
Lab area	Net area of laboratory spaces
Weather	Data can be filtered by climate zone in lieu of actual weather
Lab type	Chemical, biological, physical, other; This is proxy for operational characteristics
Lab use	Research, teaching, manufacturing, other; This is proxy for operational characteristics
Occupancy schedule	Some manufacturing facilities operate 24/7, which skews energy use intensities.
Required ventilation rates	Ventilation rates vary depending on lab use and risk factors
Equipment loads	Equipment loads vary based on the type of activity

Table 3. Different levels of benchmarking and their application

Benchmarking level	**Application**
Level 1: Whole building energy use metrics with simple data filtering for selected parameters	• Screening tool for energy managers to identify outlier facilities. • Setting organizational energy use goals [Brown 2002] • Setting energy efficiency program goals
Level 2: Whole building metrics normalized for key parameters	• Setting overall energy use targets for a specific facility • Ranking of facilities based on energy efficiency
Level 3: System level energy use metrics normalized for key parameters	• Setting system level energy use targets for a specific facility • Identifying systems with the greatest efficiency opportunities
Level 4: System efficiency metrics	• Establishing industry best practices • Setting system efficiency targets for a specific facility • Identifying specific energy efficiency strategies for each system

It is important to note that some normalizing parameters are not necessarily a given and may well present efficiency opportunities in themselves, particularly these parameters in laboratories:

- Ventilation rates: The definition of what is “required” varies considerably across different codes and standards, even for the same lab type. Within this wide range, the ventilation rate is set based on the perceived risk and risk management approach of the laboratory’s designer and health and safety officer. It is not uncommon for these to be higher than is warranted. Labs21 has documented design cases in which the ventilation rates were lowered, based on risk assessment using CFD modeling of spill scenarios [Li et al. 2003].
- Schedules: It is important to distinguish between occupancy schedules and operation schedules. It is common for some facilities to operate their building systems 24/7 even if their occupancy schedule is not 24/7. Thus, while occupancy schedules may be a given, there may be efficiency opportunities in system operation schedules.
- Equipment loads: Equipment loads in different types of laboratories can vary widely, and it is therefore important to normalize for this parameter when comparing energy use intensities across different lab types. However, this presents a difficulty in that the actual equipment loads, which are difficult to estimate, are usually much lower than the design

values. Thus, it is often the case that equipment loads are over-estimated [Brown 1996], and if energy intensity figures are normalized based on such overestimations, it will suggest that the building is more energy efficient that is actually the case.

Thus, to some degree, the question of whether a metric should be normalized for such factors involves judgment by the user of the metric, based on the context in which they apply the benchmarking results.

Benchmarking Methods for Laboratories: Regression Analysis vs. Simulation Models

Normalization is typically done with either a regression-based approach or simulation model-based approach. In the more widely used regression-based approach, a multiple regression yields an equation that relates the normalizing parameters to the metric of interest. This equation is then used to normalize the value of the metric for each building. This approach is used in EnergyStar™ [Hicks and Clough 1998], and works well provided there is a large enough representative dataset (including normalizing parameters) to run a regression [Sharp 1996, 1998]. In the case of laboratories, such a dataset does not exist. In fact, this is one of the motivations for creating the Labs21 database. Most of the EnergyStar™ benchmarking uses the CBECS database [EIA 1999]. Until recently, CBECS did not break out laboratories as a separate building type. The latest version breaks out laboratory buildings, as buildings that have more than 75% lab spaces. However, this is a limitation, because most laboratory buildings have less than 75% of net lab space - even a building that is not mixed use will typically have only 60-70% net lab space. Furthermore, lab buildings require a relatively larger number of normalizing parameters, many of which are lab-specific and not recorded in CBECS. The University of California Center for Environmental Research (CEDR) also examined methods for laboratory benchmarking and arrived at similar conclusions [Federspiel et al. 2002]. They also noted another limitation of comparing laboratories to a similar set - if the entire population is inefficient, it will cause inefficient buildings to be rated as efficient. In the case of laboratory buildings, this is of particular concern, because energy efficiency has not permeated laboratory design as it has other building types.

A simulation-based benchmarking approach addresses many of these concerns. In this approach, a simulation model is used to calculate a benchmark (typically representing an "ideal" case) against which the actual energy use can be compared. The model accounts for the relevant normalizing parameters. In the remainder of this section, we describe the Labs21 Benchmark Model and how it is used for benchmarking.[1]

In laboratory facilities, it is critical to distinguish between lab spaces and non-lab spaces, because they have significantly different operational characteristics, building systems and resulting energy use. The Labs21 Benchmark Model is a DOE-2 model that has two separate building modules, one for each space-type. Both building modules have the same geometry, size, and zoning. Each module has a separate HVAC system, with a shared central chiller and boiler. The enclosure, HVAC, and lighting specifications represent best practices, as the model is meant to be representative of an "ideal" case, against which actual energy use is to be compared. It is beyond the scope and space of this paper to fully describe these specifications, but key elements include the following:

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[1] CEDR also developed a simulation-based benchmarking approach, using a custom mathematical model. The Labs21 benchmark approach uses a DOE-2 model.

- For equipment power density, a standard value of 2 W/sf in laboratory spaces will be used unless the user has measured values of coincident peak loads for laboratory equipment. The use of design values of equipment power and schedules as user input was considered, but ultimately rejected because it is often grossly overestimated, increasing the possibility of "gaming".
- The HVAC system in the laboratory spaces is a variable volume variable temperature system with desiccant wheel heat recovery (75% efficiency). The temperature and humidity requirements are based on ASHRAE standards. The ventilation requirement (2 cfm/sf with a minimum of 1 cfm/sf) is based on standard practice. The static pressure (1.9" wg supply, 1.3" wg exhaust) is based on a study by Weale et al. [2002]. The fan efficiency (80% fan+ motor) is based on best-in-class [E Source 1997].
- The laboratory and non-laboratory HVAC systems are served by shared central chiller and boiler systems. In order for the model to work in all climates with energy recovery, three chillers and three boilers of varying capacities are specified. All pumps have variable frequency drives and high efficiency motors. The chiller energy efficiency is optimized for part-load operation.

The simulated energy use of the benchmark model in effect represents an "ideal" energy use for the facility and can be used to compute the facility's energy effectiveness ratio (EER).

$EER = e/E$
e: benchmark energy use
E: actual energy use

$e = (A_l * ei_l) + (A_{nl} * ei_{nl})$
A_l: laboratory area
A_{nl}: non-laboratory area
ei_l: benchmark energy use intensity for laboratory module
ei_{nl}: benchmark energy use intensity for non-laboratory module

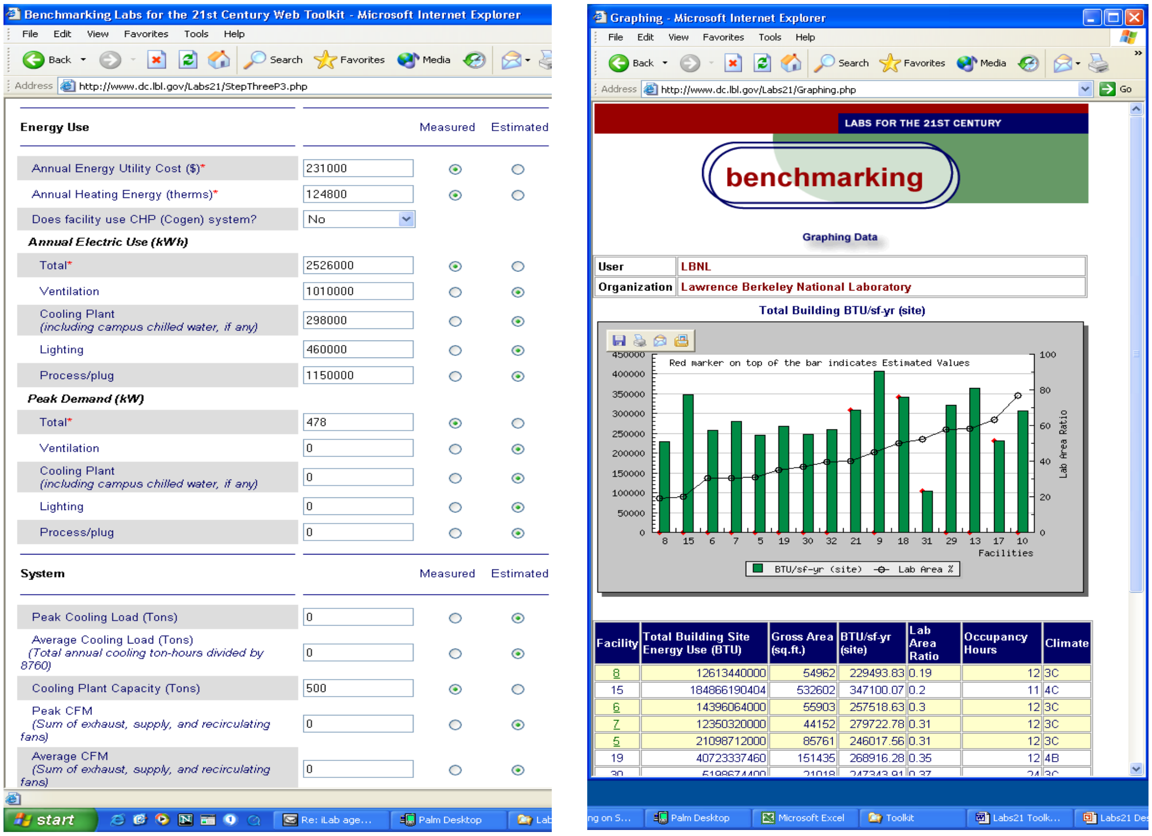
EER will be a value between 0 and 1, and the higher the EER, the more efficient the building. EER can be calculated for electricity, fuel, total site energy and total source energy. The energy effectiveness for a facility can then be compared to the energy effectiveness for any other facility, as it represents a normalized metric.

Web-Based Database Tool

Labs21 developed a web-based database tool to collect, analyze and display benchmarking data (http://www.dc.lbl.gov/Labs21/Labs21intro.php). The tool allows a user to input laboratory characteristics and energy use data via conventional web-forms. A user ID and password is required to input and edit data. The data remains anonymous to other users of the database. Although measured data is preferred, estimated data may also be provided, and the user indicates whether the data is estimated or measured. Figure 2 (left) shows a portion of the data input form. Data is manually screened for reasonableness before it is formally accepted as part of the dataset that others use for benchmarking.

In order to perform data analysis, the user specifies a metric of interest, and can set criteria to filter the data set by lab-area ratio, occupancy hours, and climate zone. There are 15 climate zones in the United States, based on a classification developed for building codes and standards [Briggs et al. 2002]. Filtering by other parameters such as laboratory type is under development. The tool then presents the data analysis in graphical and tabular format, as shown in figure 2. As of this writing, the simulation-based benchmarking has not been integrated into the web interface.

Figure 2: Labs21 Benchmarking Database Website: Data Input Form (Left), Data Output (Right)



Energy Use		Measured	Estimated
Annual Energy Utility Cost ($)*	231000	●	○
Annual Heating Energy (therms)*	124800	●	○
Does facility use CHP (Cogen) system?	No		
Annual Electric Use (kWh)			
Total*	2526000	●	○
Ventilation	1010000	○	●
Cooling Plant *(including campus chilled water, if any)*	298000	○	●
Lighting	460000	○	●
Process/plug	1150000	○	●
Peak Demand (kW)			
Total*	478	●	○
Ventilation	0	○	●
Cooling Plant *(including campus chilled water, if any)*	0	○	●
Lighting	0	○	●
Process/plug	0	○	●

System		Measured	Estimated
Peak Cooling Load (Tons)	0	○	●
Average Cooling Load (Tons) *(Total annual cooling ton-hours divided by 8760)*	0	○	●
Cooling Plant Capacity (Tons)	500	●	○
Peak CFM *(Sum of exhaust, supply, and recirculating fans)*	0	○	●
Average CFM *(Sum of exhaust, supply, and recirculating fans)*	0	○	●

User	LBNL
Organization	Lawrence Berkeley National Laboratory

Facility	Total Building Site Energy Use (BTU)	Gross Area (sq.ft.)	BTU/sf-yr (site)	Lab Area Ratio	Occupancy Hours	Climate
8	12613440000	54962	229493.83	0.19	12	3C
15	184866190404	532602	347100.07	0.2	11	4C
6	14396064000	55903	257518.63	0.3	12	3C
7	12350320000	44152	279722.78	0.31	12	3C
5	21098712000	85761	246017.56	0.31	12	3C
19	40723337460	151435	268916.28	0.35	12	4B

The database currently has data on over 40 public and private sector laboratory facilities, mostly chemical and biological laboratories, located in several different climate zones. Data collection remains a challenge. In many cases, system level data, especially measured data, could not be obtained. The next section highlights some of the results from the database.

Selected Benchmarking Results

Whole building energy use: Figure 3 indicates energy use data for a subset of the database – facilities located in cool-humid climate zone, and standard occupancy hours (less than or equal to 14 hours per day). The chart shows three quantities: total site energy use intensity in BTU/sf-yr [2],

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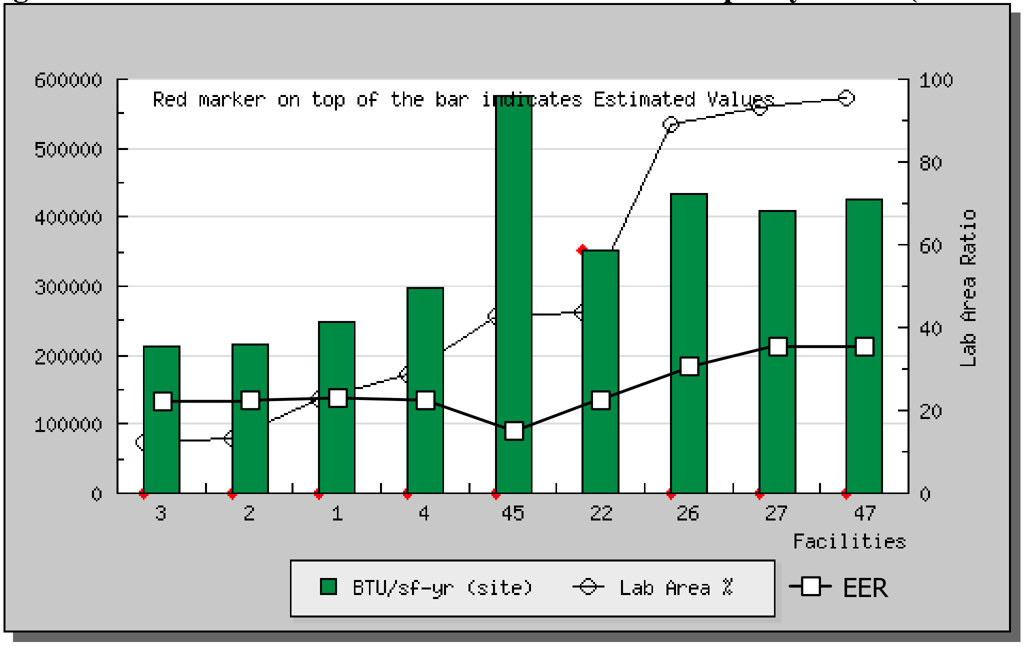
[2] Unless otherwise stated, metrics refer to gross square foot of laboratory facility.

lab-area ratio, and energy effectiveness ratio (EER). The scale for both ratios is indicated on the right-side y-axis. In all but one facility, the values for site energy use are actual measured data.

The total site energy use intensity varies from about 200,000 BTU/sf-yr to almost 600,000 BTU/sf-yr. For comparison, the average office building site energy use intensity in the U.S. is about 90,000 BTU/sf-yr [EIA 1999]. This chart clearly illustrates the correlation between the energy use intensity and the lab area ratio, underscoring the importance of normalizing for this parameter when comparing labs. The EER normalizes for lab area ratio as well as weather differences within this climate zone. EER indicates that facilities 27 and 47 are actually more energy efficient that facilities 1,2, and 3, which have lower energy use intensities.

Figure 3. Site Energy Use Intensity (BTU/sf-yr) and Energy Effectiveness Ratio (EER) for Buildings in Cool-Humid Climate Zone and Standard Occupancy Hours (<= 14 hrs/day)



Peak loads and plug loads: Figure 4 shows the peak electrical loads for all facilities for which data were available. Note that about 70% of these values are from actual measured data. Of particular interest is the relationship between these measured total peak electrical loads and estimated peak plug loads used during design. Figure 4 shows that none of the facilities have *total* peak electrical loads more than 15 W/sf. Yet, it is common for designers to assume plug loads *alone* at 10-12 W/sf or more. These data, albeit limited, reinforce the argument that plug loads are often significantly overestimated, leading to oversized mechanical and electrical equipment, which in turn results in wasted first cost, and inefficient operation. This suggests that measured data should be used for estimating plug loads, and allowances for future growth should be taken judiciously.

Ventilation system efficiency: Figure 5 shows the ventilation system efficiency in terms of peak W/cfm, counting all supply *and* exhaust fans' rated power and rated cfm. This metric is fairly independent of operating parameters such as weather and is largely driven by air handler efficiency and pressure drop. Therefore, a high value for this metric almost always indicates an opportunity to reduce energy use through efficient fans, motors, and low-pressure drop design features. Exceptions to this axiom would be laboratories that have unusually high filtration requirements, or that incorporate an energy recovery system. The benchmarks for standard, good and better practice indicated in the figure are based on a paper by Weale et al. [2002], which recommends several strategies for low-pressure drop design, including lower face velocity for air handler coils, appropriate design and selection of VAV dampers and zone coils, larger ducts with shorter duct runs, and staged exhaust stacks.

Figure 4. Total Peak Electrical Load (W/sf).

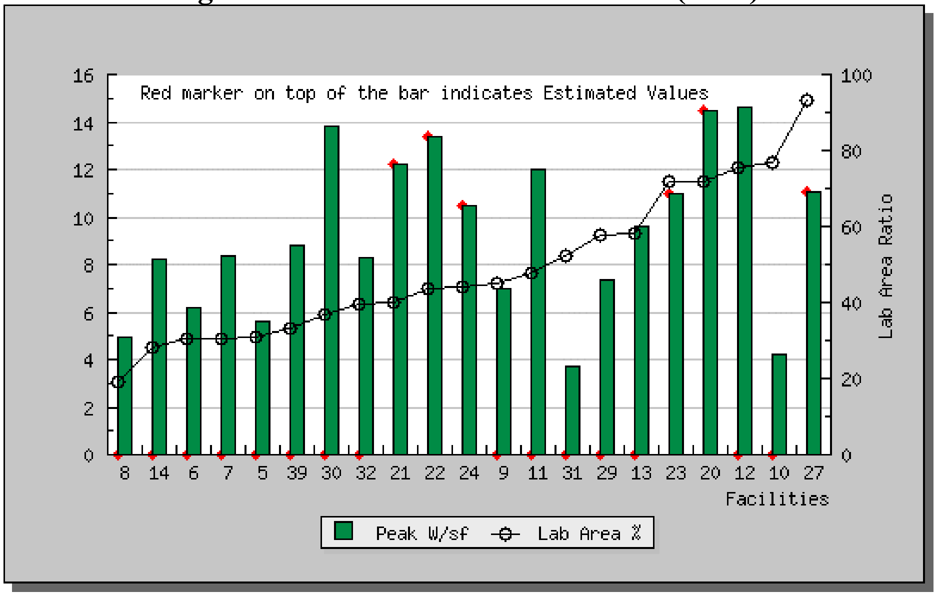
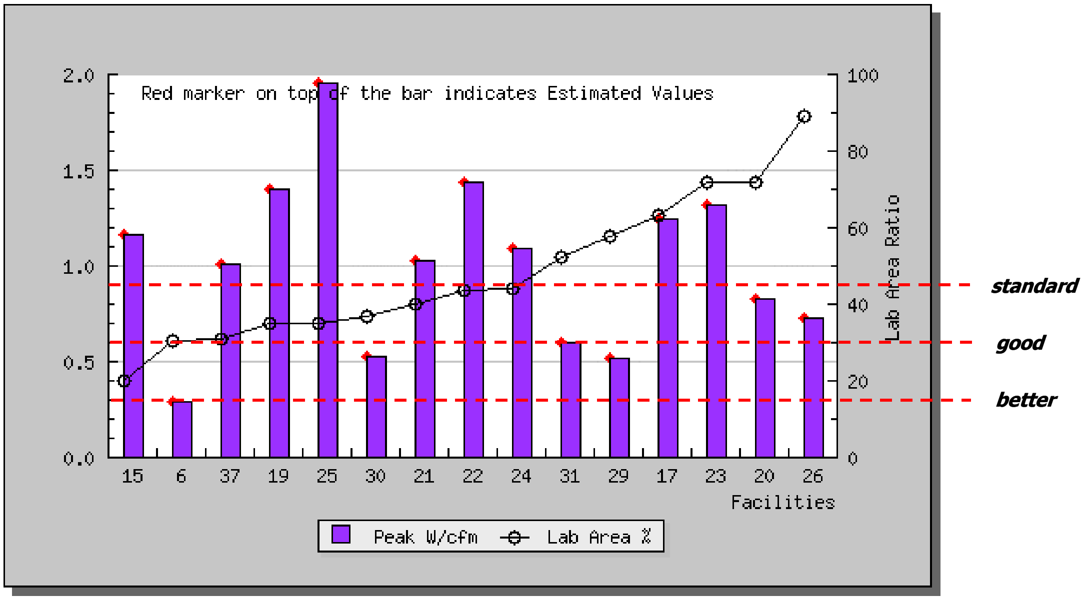


Figure 5. Aggregate (Supply and Exhaust) Ventilation System Efficiency (w/cfm). Benchmarks for Standard, Good, and Better Practice are Based on Weale et al. [2002]



Labs21 Environmental Performance Criteria

Overview

While the benchmarking tool described above specifically addressed energy use metrics at the building and system level, the Labs21 Environmental Performance Criteria (EPC) is a rating system for use by laboratory building project stakeholders to score the broader environmental performance of laboratory facilities (http://www.labs21century.gov/toolkit/epc.htm), particularly for new construction. Currently, the U.S. Green Building Council's LEED™ Rating System [USGBC 2002] is the primary tool used. However, LEED™ was designed for U.S. commercial office buildings and as such, lacks some attributes essential to encouraging the application of sustainable design principles to laboratory buildings (e.g. managing laboratory effluents).

The EPC was developed through a series of working groups involving over 40 industry volunteers, including architects, engineers, consulting experts, health & safety personnel, and facilities personnel. It is currently being used as a basis for a new LEED™ application guide for laboratories, which is being developed by the USGBC.

The Labs21 EPC follows the format of LEED™ Version 2.1. The EPC has additional credits and prerequisites and in a few cases has modifications to the existing LEED™ credits. Table 2 summarizes the key issues addressed with new credits and prerequisites.

Table 2. Key Issues Addressed in New EPC Credits and Prerequisites

LEED Section	EPC credits and prerequisites
Sustainable sites	Credit for physical or mathematical modeling of air effluents to ensure compliance Credit for elimination of effluents to sanitary sewer using containment controls
Water efficiency	Prerequisite to eliminate "once-through" cooling Credits to document process water baseline and reduce by 20%
Energy and atmosphere	Prerequisite to optimize minimum ventilation requirements Modified LEED™ energy efficiency credit to account for lab systems Modified LEED™ renewable energy credit by reducing thresholds Credit for reducing source non-renewable energy using on-site generation Credit for energy efficient laboratory equipment Credit for right-sizing HVAC based on measured lab equipment loads
Materials and resources	Prerequisite to ensure information system to track hazardous materials Credit to limit quantities, storage and waste of hazardous materials
Indoor environmental quality	Prerequisite to meet ventilation requirements of ANSI-Z9.5 Credit to optimize indoor airflow based on CFD or physical modeling Credit to conduct fume hood commissioning per ASHRAE-110 as installed Credit for designing all alarm systems to be inherently self-identifying and failsafe

The EPC is more heavily weighted towards energy & atmosphere credits than LEED™ 2.1, because energy use has a more significant environmental impact in laboratories when compared to other commercial buildings. In the remainder of this section, we focus on the energy-related credits.

Energy & Atmosphere

Given the significance of energy use in laboratory buildings, this section dominated the development of the EPC, and contains several additions and modifications to LEED™.

Energy efficiency. Generally, there are two approaches to address energy efficiency requirements, each with associated advantages and disadvantages.

- Prescriptive Approach: This approach would essentially give points for implementing certain energy efficiency measures (e.g. VAV fume hoods). This approach is easier to specify, but also has less flexibility to the design team to meet the intent of the credit.
- Performance approach: This approach would define a baseline energy performance and give points for percentage reductions from the baseline. This approach is conceptually preferable, but more difficult to specify and verify.

LEED^{TM} adopts a performance-based approach and uses the ASHRAE 90.1 energy cost budget method (ECB) [ASHRAE 1999] as the benchmark, with points awarded for reductions below the benchmark. However, ASHRAE 90.1 ECB does not suitably address baseline assumptions for laboratory systems. The EPC development team chose to maintain the performance-based approach, using ASHRAE 90.1 ECB, but modifying it to include specifications for laboratory systems parameters, including:

- Fume hood configuration (e.g. 100 fpm face velocity, vertical sash at 18" opening)
- Ventilation system control
- Lighting power density

Furthermore, recognizing that ventilation is typically 50% of laboratory energy use, the EPC adds a prerequisite to ensure that ventilation requirements are optimized. As ventilation requirements cannot be universally prescribed, the prerequisite instead prescribes a process that requires: a) a team-based decision-making process; b) consideration of exhaust alternatives for fume hoods; and c) fume hood sash management plan.

There is legitimate concern that a performance-based approach can be "gamed", especially in laboratory facilities, with all their inherent assumptions on functional requirements. To address this issue, Labs21 is currently developing a set of modeling specifications for laboratory systems, which will serve to supplement the specifications already in ASHRAE 90.1. These guidelines will also be incorporated into the Labs21 simulation model-based benchmarking tool, described earlier.

Energy supply. LEED^{TM} Credit 2 provides points for on-site renewable energy generation, expressed as a percentage of the building's total energy use. Because laboratories typically have 3-5 times the energy intensity of an average commercial office building, the percentage values in LEED^{TM} are consequently 3-5 times as hard to achieve for laboratories. In order to compensate for this, the EPC reduces the percentage thresholds for each point.

Due to their high energy loads and need for back up generation, laboratories are often good candidates for cogeneration systems. While LEED^{TM} rewards energy efficiency and renewable energy, it does not currently reward source energy reductions through the use of co-generation systems. The EPC adds a credit for energy efficient on-site generation, with points awarded based on percentage reductions in source energy use, when compared to grid-supplied electricity and fuel. By using source energy as the metric, the credit provides flexibility as regards system type, system efficiency, waste heat utilization, etc.

One issue pertinent to on-site generation is emissions. Ideally, this credit should establish a baseline for emissions. As there are no national standards, the credit currently requires just meeting local standards. As national standards emerge, they can be incorporated.

Laboratory equipment efficiency. Equipment loads in laboratories are typically much higher than commercial buildings and can vary widely, from 2 W/sf to over 15 W/sf. In addition to direct consumption, equipment loads also affect cooling energy use. Equipment loads are often overlooked as an area for increased efficiency. LEED™ does not currently reward energy efficiency in this arena. The EPC adds two credits to encourage reducing equipment loads.

- Credit for selecting equipment that is above the 75th percentile of its class of functionally equivalent equipment, in terms of efficiency. This criterion reflects the EnergyStar™ approach. (EnergyStar™ does not have ratings for laboratory equipment.)
- A credit for measuring base usage of equipment electrical loads in a comparable laboratory space and designing electrical and mechanical systems based on these measurements.

Toward LEED™ for Labs

As noted earlier, the USGBC is in the process of developing and publishing a LEED™ Application Guide for Laboratories ("LEED for Labs"), using the EPC as a basis for this effort. Some issues that have not yet been fully addressed include:

- Building type definition: Thus far, LEED™ has been applied uniformly to all building types i.e. building type is not an issue. However, with the development of LEED™ for different building types, it is necessary to define how it will be applied to mixed-use buildings.
- Weighting of credits: This issue is inherent to any rating system that has criteria in multiple domains, e.g. "Is a 5% reduction in energy as beneficial as a 20% reduction in water use?"
- Number of points: This version of the Labs21 EPC increases the number of possible points from 69 to 85. This requires a commensurate change in the threshold values for certification and the ratings of silver, gold and platinum.

Conclusions and Lessons Learned

Complex buildings such as laboratories are energy intensive and have significant energy efficiency opportunities. From the standpoint of benchmarking and rating systems, complex buildings may be defined as those that have special or unusual functional requirements (e.g. health and safety) that directly and significantly impact sustainability criteria. Such buildings challenge the conventional approaches to benchmarking and rating systems and require appropriate adaptations to these approaches. In this paper, we described two tools: one for benchmarking building and system level energy use in laboratories and one for scoring broader environmental performance, using an adaptation to the LEED™ rating system. Some lessons that apply to laboratories and complex buildings in general include:

- Normalizing for functional requirements. For complex building types, the variations in functional requirements are invariably much larger than in other building types e.g. the variation between chemical laboratories and physical laboratories vis-à-vis ventilation rates and plug loads. On the other hand, the definition of what constitutes a requirement is often open to interpretation, and should not necessarily be taken at face value (ventilation rates in laboratories are the most telling example of this).
- Simulation model-based benchmarking is invariably the most feasible approach for whole building energy benchmarking in complex buildings, given the general paucity of data, compounded by the data requirements for normalization for various functional requirements. [3]
- Benchmarking using system-level metrics assists designers in identifying opportunities for greater efficiency.
- Complex building types require adaptations of the LEED™ rating system, to address areas that are absent in LEED™, such as health and safety issues. While a performance-based approach to defining credit requirements is generally preferable, this can be challenging if there are no widely accepted standards. In such cases, the credit could focus on design process requirements. For example, the EPC credit on air effluents requires the study of air effluents via CFD or wind tunnel modeling. The premise is that a conscientious design effort will increase the probability of a better design, just as commissioning does.
- From the standpoint of maintaining the consistency and "brand identity" of LEED™ across different building types, the adaptations should as far as possible maintain all the existing LEED™ credits (the EPC modifies only three LEED™ credits). With appropriate guidelines and standards for creating special versions for complex buildings, LEED™ can broaden its scope while maintaining overall consistency.

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[3] One notable exception to this is the EnergyStar™ rating for acute care hospitals, which utilized an EPRI database of hospital energy use data, allowing for a regression-based approach. However, given the complexity and variation between different types of hospitals, it cannot be assumed that this rating can be applied broadly to all types of hospitals.

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