Sustainable Laboratory Design and Construction

Sponsored by:

SIEMENS

Supplement to:

R&D

Laboratory Design

Sustainability Basics and Design

Lower energy operating costs outweigh the extra cost to install sustainable systems.

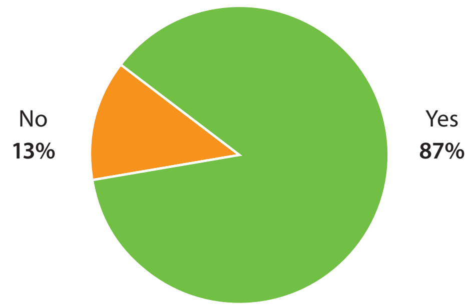
Over the past decade, it has become readily apparent that the global environment is increasingly sensitive to human activity. The effects of global warming, increasing energy costs, dramatic climate changes and shortages of raw materials, potable water and food strain the global community. To maintain economic growth with diminishing resources, reduce the vast emissions and waste products we create and provide for a healthy and comfortable future work environment, numerous initiatives have been started to create sustainable activities. These sustainability philosophies now permeate all aspects of human society. In this report, we focus on those implementations targeted toward the creation and operation of the modern research laboratory.

Sustainability in the design, construction and operation of a research lab involves reducing the overall costs of each segment (design, construction and operation), reducing the resources required by each and the overall waste products generated. The overarching goal of lab managers in their sustainability efforts is to build and operate their labs in the most natural manner possible and in ways that either minimize or negate the research lab's effects on the environment.

Architects, scientists, engineers, lab planners and designers investigate all the available aspects of accomplishing these goals when planning and designing a new or renovated research lab. In the design phase, lab developers may focus on lab aspects such as siting, solar orientation, drainage, landscaping, seasonal weather variations, access to transportation resources, flow of researchers through the proposed facility and urban settings. In the construction phase, they may focus on the use or reuse of local materials, minimization of construction-based pollution effects, protection of natural habitats, sensitivity to brownfield areas and reduction of construction waste materials.

And in the operational phase, they look at ways to decrease the heating and cooling requirements; increase the researchers' workplace lighting capabilities and reduce the volume of chemicals, gases and other basic materials, all while maintaining or increasing the researchers' safety and security.

Is Having a "Green Lab" Important?



Contents

Editor's Note: The analysis, tables and charts presented in this report summarize responses to surveys on Sustainable Laboratory Design and Construction performed by the editors of R&D Magazine *and* Laboratory Design Newsletter *in 2014. All graphics and data are copyright by Advantage Business Media, 2014.*

Sustainable Design

The complexity and performance requirements of research labs present unique challenges in sustainable design over that of traditional industrial structures. In addition to these functional requirements, new research labs are now often mandated to incorporate sustainable design strategies; and many are even required to obtain LEED (Leadership in Energy and Environmental Design) certification (see Section 2).

Having a sustainable, or "green" lab is considered an important personal feature to researchers. According to recent reader surveys performed by the editors of *R&D Magazine* and *Laboratory Design Newsletter*, nearly 90% of those surveyed considered having a "green lab" as important. Of those not considering implementing a "green lab" project, their objections center on costs and size (their labs are too small to install sustainable systems). However, employing a sustainable design philosophy during each phase of a new or renovated research lab design process reduces the negative impacts of that project on the environment and researchers, while minimizing the effects on the overall costs.

Costs are certainly an important aspect of implementing a sustainable lab design. The researcher survey respondents, consisting primarily of research lab directors, consulting engineers and architects, facility managers and research scientists and engineers, stated that the most important consideration in pursuing development of a sustainable lab was for energy savings and efficiency—this aspect was chosen by nearly two-thirds of the survey respondents. Other considerations noted by the survey respondents include the price of implementing sustainable designs (a negative consideration), safety (a strong choice in any survey on research labs), compliance and LEED certification.

Initial Steps

One of the first steps in designing a new sustainable (or other) research lab is in the site selection for the facility. Site selection involves a wide range of criteria that can have a dramatic effect on the sustainability of the completed lab. Site selection also can be concerned with not picking the wrong site, such as prime farmland, flood plains, endangered habitats, near wetlands, near bodies of water identified by the Clean Water Act as usable for recreational use and public parklands.

The positive aspects of site selection can include picking sites that are located on previously developed sites; located near public transportation access to reduce pollution from automobile use and picking a site where existing vegetation can reduce the need for creating new stormwater management infrastructures. Of course, each facility and site will have its own particular factors that involve sustainability issues and other non-sustainability-related research lab issues as well.

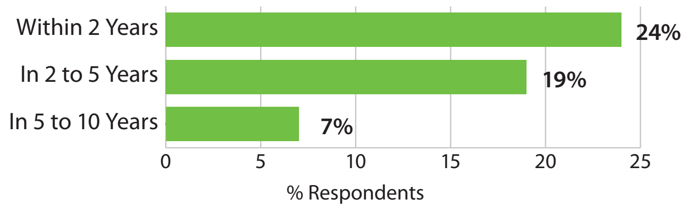
A partial checklist of things to consider and look for in site selection for a sustainable research lab can include:

- Access to academic facilities
- Access to locally manufactured/supplied materials
- Access to traditional shipping routes/modes
- Ecological restoration possibilities
- Environmentally sensitive areas
- Existing and potential parking characteristics
- Historical uses
- Mass transit access
- Natural drainage patterns
- Natural vegetation
- Potential building configuration placement choices
- Potential employee housing distribution map
- Prevailing weather patterns
- Soil analysis and contamination concerns
- Solar orientation
- Stormwater retention capabilities
- Surface and subsurface rock strata
- Topographical survey
- Traditional insect habitat
- Utility access for special purpose lab equipment
- Zoning and neighborhood characteristics

Planning and Programming

Following site selection, the overall design plan for a sustainable research lab is at the heart of meeting the facility's primary sustainable design requirements. It's during these discussions that the following items will be established and detailed for optimizing the lab's overall sustainability performance. Software-based modeling and simulation systems are often used to choose the final configuration based on sustainability, energy use, productivity and numerous other attributes. Actual

When Install Green Technologies?

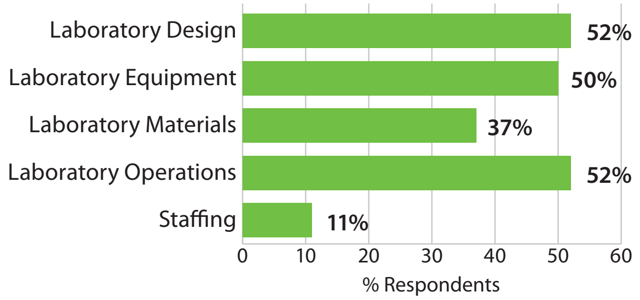


full-size models of lab modules can also be made to verify the researchers' needs, interactions and productivity capabilities. And while all involved parties participate in these discussions, sustainability features are accompanied by numerous other considerations with each having its own champions.

Alternative energy considerations – Photovoltaic (PV) solar panels are increasingly installed on research lab rooftops as a renewable on-site energy supplement option to increase the lab's energy sustainability. Falling prices for PV panels, along with an increasing installed base and number of installers, have enlarged this particular enhancement. Other renewable energy sources can also be considered in these discussions, such as wind turbines, biomass fuel generators, landfill-derived methane fuel generators, fuel cells and co-generation. These latter options are generally complex, expensive and require substantial expertise and real value capabilities. They require substantial investments up front and have longer ROIs (return on investments) than the relatively simpler PV. They are often considered as add-ons for existing facilities, where specific gains are needed to improve the existing operating systems.

Fenestration – Window sizes, designs, locations and treatments are increasingly used to allow natural light as deep into the labs as possible, thereby minimizing the amount of artificial lighting and resulting energy usage that is required to be installed and used. Heat gains and losses can also be obtained with various window designs that affect the facility's overall sustainability. Advanced window technologies allow designers to select from a choice of spectral transmission values so visible light can enter the building, while heat-producing infrared wavelengths are reflected. Substantial calculations, however, often are required to fully understand the levels of solar energy gains and effective shading coefficients, all as a function of building mass.

Where Sustainable Projects Reside



Interstitial floor considerations – Interstitial floors are utilized above and below special-purpose lab configurations such as biosafety labs (BSLs), where general access for maintenance or equipment installations are often restricted or

Why Should Researchers Design Sustainable Labs?

Reduce Energy Consumption / Costs	28%
Environmental Responsibility	28%
Meet Government Sustainability Goals	14%
Encourage Good Behaviors	7%
Compliance	5%
Improved Lab Efficiency	5%
Improved Operational Performance	4%
Increased Lab Safety	2%

disruptive to the ongoing lab operations. The real sustainable value to the installation of interstitial spaces can be questioned, since they add real and volumetric spaces, as well as effective heating and cooling loads, to the overall building.

Lighting considerations and option selection – Increasingly LED lighting systems are installed to replace the higher energy requirements of incandescent and fluorescent lighting systems. When tied in with the fenestration designs noted above, LED light systems can provide major sustainability gains through reduced electrical energy requirements. The actual level of lighting required within a lab space should also be considered through conversations with users, lighting specialists and equipment suppliers. The actual level and type of lighting installed within a lab is often strongly dependent upon the research performed within the lab—i.e., visual inspection of samples requires higher lighting levels; fluorescent studies often require lower lighting levels. Sustainable lighting systems shouldn't compromise the actual research being performed.

Lab module design – The design, spacing and configuration of these building blocks are tied to many aspects of the research lab's operation, not the least of which is sustainability. Lab flexibility, productivity, special-purpose operations, maintenance, safety and other considerations are tied to the final configurations of these systems that are mostly specific for each facility.

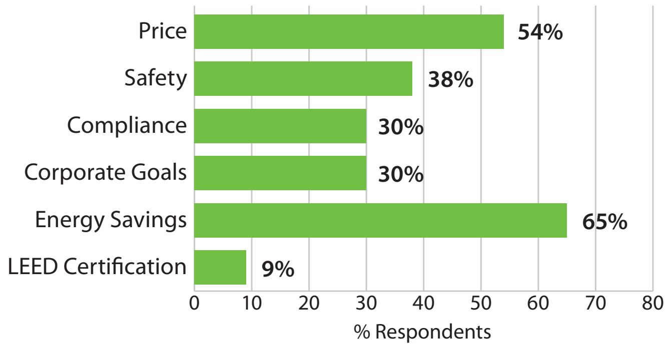
MEP system configurations – Selection of the mechanical, electrical and plumbing systems and supplies for the research lab can be looked at from a sustainability viewpoint in terms of the most efficient systems, the most efficient number of systems installed per lab module and their actual required safe and effective implementation.

Office-lab configurations – Productivity, safety and lab flexibility are tied to this strong sustainability-based feature of the research lab. Again, these configurations are very specific to individual facility preferences. These configurations are often based upon the lab managers' and researchers' personal preferences, although recent trends are to place the offices in close proximity to the labs to provide greater interactions with the actual research. Safety and security considerations must be considered in these situations to ensure that potentially hazardous operations in the lab don't compromise the safety of the general office population. The actual sustainability of these configurations can vary greatly based upon the lighting configurations, effective ventilation requirements and lab bench area requirements.

Sizing – Smaller is better from a sustainability standpoint (due to lower energy requirements), but this must be tied to researcher preferences, overall workload and lab module designs. Floor heights, the number of labs, the number of floors, the overall gross and net area sizes and resulting floor plans can have significant differences in overall sustainability effects. Software-based modeling systems can provide real benefits in estimating the sustainable energy, lighting, materials and indoor environmental quality values for several different configurations.

Ventilation and fume hood specifics – Traditional fume hoods are the largest energy hogs in the research lab, consuming enough energy per fume hood to satisfy the individual energy requirements of several residential houses. With the increasing acceptance of ductless fume hood systems (with their substantially smaller energy requirements, 20% or less) and the increasing number of suppliers and options, this has seen some of the largest sustainability gains in the overall design and planning phase of research labs. These systems are also

Why "Green" Lab



highly regarded for renovation projects where older ducted fume hoods can be replaced, thereby reducing the operating energy requirements. In labs where ducted fume hoods are still required, sash control systems, occupancy sensors and low-flow fume hood systems can be implemented to substantially reduce the overall operational energy requirements of the lab.

Heat-recovery systems – Variations in heat-recovery systems for the overall heating and cooling systems for research labs include energy-recovery wheels, heat pipes and runaround loops. Energy-recovery wheels, with sensible and latent heat recovery were found to be cost effective in all climates according to I^2SL comparisons.

LEED

Updated rating system includes broader focus on sustainable technologies.

Leadership in Energy and Environmental Design (LEED) is a sustainability certification rating system developed by the U.S. Green Building Council (USGBC). The USGBC is a private, membership-based non-profit organization that promotes sustainability in how buildings are designed, built and operated. The USGBC partners with the Green Building Certification Institute (GBCI), offering a suite of LEED professional credentials that identify expertise in the field of green building. Those involved in the development of sustainable research labs and accredited by the USGBC often have the LEED AP (Accredited Professional) added to their title.

Developed in 2000, LEED has become the nationally accepted benchmark tool for the design, construction and operation of high-performance sustainable buildings. The rating system (see attached table) has a maximum of 100 base points with an additional six possible for Innovation in Design and four in Regional Priority areas. There are four ratings possible with 40 to 49 points yielding a Certified Award, 50 to 59 getting a Silver Certificate, 60 to 79 getting a Gold Certificate and anything over 79 getting a Platinum Certificate. Upgraded several times since its inception, the current version is LEED v4, which was released on November 20, 2013, and supersedes LEED 2009. The new LEED v4 release adds new categories that weren't included or identified in the 2009 release. Specifically, new categories in v4 include climate change, human health, water resources, biodiversity, green economy, community and natural resources. The first LEED v4 project certification announced on November 20, 2013, was a LEED v4 Gold for the Haworth Beijing Organic Showroom, located in Beijing, China.

Within each of the seven LEED credit categories, applicants must satisfy that their projects satisfy particular prerequisites and earn points. The last two categories address sustainable building expertise as well as design measures not covered under the five environmental categories.

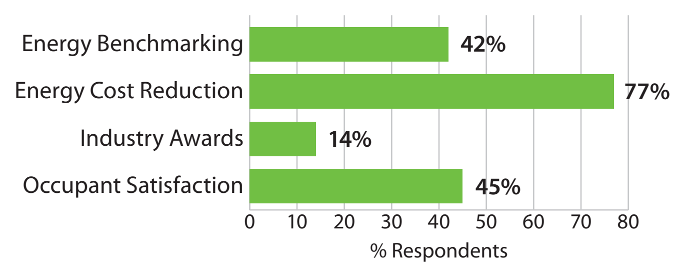
LEED certification is applicable across a wide range of buildings including new construction and major renovations, existing buildings, commercial interiors, core and shell and even schools and private residences. There are currently over 4.5 billion ft^2 of construction space involved with the LEED system, with more than 1.5 billion ft^2 LEED certified to more than 7,000 projects in the U.S. and 30 countries. Many U.S. federal agencies and state and local governments now require LEED certification.

LEED Categories

The Location and Transportation category examines the programs developed to minimize the energy use and pollution created by personal vehicles, while also minimizing the building's impact on the surrounding neighborhood/environment. A special line in this category—LEED for Neighborhood Development—looks to avoid development on inappropriate sites and to reduce the vehicle miles traveled, while enhancing livability and improving human health by encouraging daily physical activity. These projects are required to be located within the boundary of a development certified under LEED ND (Stage 2 or Stage 3 under the Pilot or 2009 rating systems, Certified Plan or Certified Project). Projects attempting this LEED credit are not eligible to earn other Location and Transportation credits.

The Sustainable Sites design criteria minimizes a research lab's impact of ecosystems and waterways, while encouraging regionally appropriate landscaping and water management. The Water Efficiency category concerns the smart use and reduction of potable water requirements through more efficient fixtures and appliances and smarter landscaping efforts.

Validation of "Green Lab"



The large point-value (33 points) Energy and Atmosphere category involves energy strategies for commissioning; energy use monitoring; efficient design and construction; efficient appliances, systems and lighting; use of renewable and clean energy sources and other innovative strategies.

The Materials and Resources category involves the selection of sustainably grown, harvested, produced and transported products and materials. It promotes the reduction of waste, while promoting reuse and recycling efforts.

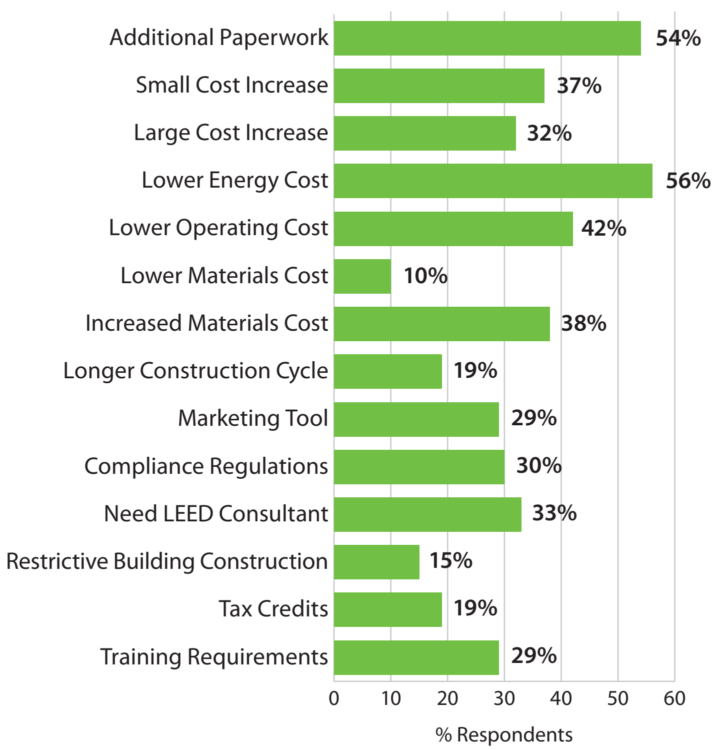
The Indoor Environmental Quality category establishes the minimum indoor air quality (IAQ) requirements to enhance indoor air quality in research labs, thus contributing to the comfort and well-being of the researcher occupants. This particular category relies on ventilation systems meeting or exceeding the minimum outdoor air ventilation rates as described in the appropriate ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) standard.

Other Rating Systems

There are other resources also available for rating the research lab design and construction process. The Buildings Research Establishment Environmental Assessment Method

(BREEAM) was created in the U.K. in 1990 to rank building systems, components and materials based on the carbon impact of each decision. This system includes an assessment in nine different categories: Management, Health and Well-Being, Energy, Transport, Water, Materials and Waste, Land Use and Ecology, Pollution and Innovation. Each submitted project receives a score for each of these nine categories and is assigned a weighting according to the environmental impact of each category. The resulting scores reveal the project's achievement in one of five levels—Pass, Good, Very Good, Excellent and Outstanding. While there is no specific category for research labs, applicants submitting research labs find they fit into the BREEAM Other Building section.

LEED Effects on Lab Design and Construction



The International Institute for Sustainable Labs (I²SL)—formerly known as the Labs21 organization which was initiated by a partnership between the U.S. Dept. of Energy and the Environmental Protection Agency—was founded to develop tools and resources for high-efficiency lab facilities. I²SL offers a Labs21 Tool Kit consisting of resources that support the design, construction and operation of high-performance labs. The Tool Kit includes design guides, case studies, a performance rating system (formerly the Environmental Performance Criteria, or EPC), a video and other products under development.

LEED and Labs

The LEED rating system doesn't specifically identify research labs, there was a collaboration between the USGBC and the Labs21 organization to create a guideline for labs about 10 years ago, but that work wasn't completed. The Whole Building Design Guide—a program of the private, non-profit Washington, D.C.-based National Institute of Building Sciences—has created a guide on *Using LEED on Laboratory Projects* that is available on their Website, www.wbdg.org/resources/lableed.php. This guideline was created for LEED 2009 and may need some updating for LEED v4.

When asked how lab researchers can validate the design efforts put into creating a LEED-certified research lab, they responded overwhelmingly with the energy cost reductions they see with their new labs. More than three-quarters of the survey respondents chose this as their primary response. Energy benchmarking validation and occupant satisfaction were the second highest responses, with slightly less than 50% response rates.

Looking at the overall effects of creating a LEED-certified research lab, more than half of the survey respondents stated that increased paperwork and lower energy costs were the largest effects they saw. Other effects noted included lower operating costs (42% of the survey respondents) and increased material costs during construction (38%). About a third of the survey respondents noted having a small cost increase due the LEED certification process, while another third stated that they saw a large cost increase due to the sustainable enhancements.

While energy reductions and the resulting reductions in utility bills were the primary results of these sustainable design additions, few researchers noted that they used the enhancements as a marketing tool for their organization (29%), and fewer still stated that they received any tax credits for their efforts (19%). Similarly, only a few researchers noted that the enhancements extended the normal construction cycle time (19%), while about a third of the researchers noted that they needed a LEED consultant to take full advantage of the sustainability enhancements.

The Cost of LEED

There are several costs involved for LEED—the cost of implementing the design changes themselves and the actual registration and certification costs paid to the GBCI. The latter costs are generally smaller, approximately \$0.03 to \$0.05/ft² for new construction. There also is the documentation cost for compiling and submitting the LEED forms and managing the compliance process. There also might be the cost for an outside consultant hired specifically for the LEED submission, which could be a staff member of an architectural or design firm, the general contractor or both. The LEED process itself can introduce extra design costs for commissioning, which could amount to \$0.50 to \$1.00/ft² for a complex research lab. Commissioning isn't absolutely required, but callbacks could require it at an enhanced cost beyond the original estimate. The General Services Administration (GSA), for example, requires commissioning for all of its projects. Energy modeling costs can also be added into this mix, and are an added step for the LEED process beyond

LEED v4 for New Construction and Major Renovation Projects

Checklist

Location and Transportation	**16 Possible Points**
LEED for Neighborhood Development Location	16 Points
Sensitive Land Protection	1 Point
High-Priority Site	2 Points
Surrounding Density and Diversities	5 Points
Access to Quality Transit	5 Points
Bicycle Facilities	1 Point
Reduced Parking Footprint	1 Point
Green Vehicles	1 Point
Sustainable Sites	**10 Possible Points**
Construction Activity Pollution Prevention	Required
Site Assessment	1 Point
Site Development – Protect or Restore Habitat	2 Points
Open Space	1 Point
Rainwater Management	3 Points
Heat Island Reduction	2 Points
Light Pollution Reduction	1 Point
Water Efficiency	**10 Possible Points**
Outdoor Water Use Reduction	Required
Indoor Water Use Reduction	Required
Building-Level Water Metering	Required
Outdoor Water Use Reduction	2 Points
Indoor Water Use Reduction	6 Points
Cooling Tower Water Use	2 Points
Water Metering	1 Point
Energy and Atmosphere	**33 Possible Points**
Fundamental Commissioning and Verification	Required
Minimum Energy Performance	Required
Building-Level Energy Management	Required
Fundamental Refrigerant Management	Required
Enhanced Commissioning	6 Points
Optimize Energy Performance	18 Points
Advanced Energy Metering	1 Point
Demand Response	2 Points
Renewable Energy Production	3 Points
Enhanced Refrigerant Management	1 Point
Green Power and Carbon Offsets	2 Points
Materials and Resources	**13 Possible Points**
Storage and Collection of Recyclables	Required
Construction and Demolition Waste Management Planning	Required
Building Life-Cycle Impact Reduction	5 Points
Building Product Disclosure and Optimization Environmental Product Declarations	2 Points
Building Product Disclosure and Optimization Sourcing of Raw Materials	2 Points
Building Product Disclosure and Optimization Material Ingredients	2 Points
Construction and Demolition Waste Management	2 Points
Indoor Environmental Quality	**16 Possible Points**
Minimum Indoor Air Quality (IAQ) Performance	Required
Environmental Tobacco Smoke (ETS) Control	Required
Enhanced IAQ Strategies	2 Points
Low-Emitting Materials	3 Points
Construction IAQ Management Plan	1 Point
IAQ Assessment	2 Points
Thermal Comfort	1 Point
Interior Lighting	2 Points
Daylight	3 Points
Quality Views	1 Point
Acoustic Performance	1 Point
Innovation in Design	**6 Possible Points**
Innovation	5 Points
LEED Accredited Professional	1 Point
Regional Priority	**4 Possible Points**
Total	**110 Points**

any initial modeling work. LEED modeling costs start at $5,000 to $10,000 and can go beyond that depending upon the project complexity.

These overall LEED costs are mostly based on LEED 2009 applications. The recently announced LEED v4 is moderately different than the 2009 version, and may have slightly different cost values—and likely more expensive that include additional costs for the changes noted.

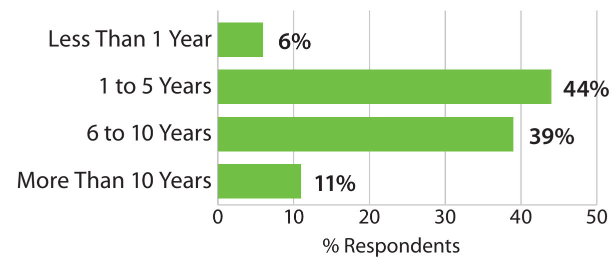
The final cost add-ons are the actual construction costs of implementing the sustainable components. This can be equalized by the anticipated operating cost reductions. However, numerous studies, including our own, for the construction costs alone have resulted in a typical premium for LEED projects of 2 to 15%, with the high end including a lot of the on-site renewable energy generation components, such as rooftop-mounted photovoltaic arrays.

Green Construction

Managers look at simple, practical ways to build and implement a 'green' lab.

Building Information Modeling (BIM) software systems are utilized across a wide range of new construction facilities, including research labs, to coordinate the implementation of sustainable designs. BIM systems incorporate information from various sources into a single integrated database that is available to all participants (architects, engineers, consultants, building owners and construction managers) in the design and construction process. The 3-D computer-based BIM system has become the glue that ties together the initial design, the facility construction and the completed building operation and performance modeling. Changes at any step in this process can be tracked and coordinated continuously, with overall plans adjusted appropriately. Being a primarily visual tool (3-D modeling), the BIM system clearly communicates the client's requirements, containing parametric information and up-to-date amendments. Materials tracking and construction scheduling can all be integrated into the detailed designs.

Is Having a "Green Lab" Important?



BIM systems can also be used to directly feed information on the facility's structural analysis, environmental performance, energy use, thermal comfort analysis and daylighting and lighting analyses. From a sustainability standpoint, these modeling systems can calculate the building thermal properties and ensure that the structure isn't compromised by any sustainability issues. It also can track that the required energy and comfort targets created in the initial design are maintained throughout the construction process. To obtain these wide-ranging calculations, basic architectural BIMs are integrated with a structural BIM and a mechanical-electrical BIM system.

During the construction phase, these BIM systems have the ability to detect inconsistency (clashes) ahead of time and create an appropriate resolution. These clash detection and clash resolution events are generally undertaken with specialist software systems integrated into the BIM model. Detailed interrogations by the project participants can be made with appropriate clash detection reports created.

The Do's and Don't's of Sustainable Lab Design and Construction

DO	DO NOT
Start with the low-hanging "fruit"	Use unusual or designed items—too expensive
Involve all parties that are affected	Employ extra bells and whistles that are not essential
Use as much natural lighting as possible	Sacrifice or compromise on safety
Reduce generated waste	Spend uncontrolled
Do everything possible to facilitate use of mass transit	Have too short of a payback expectation
Ask users what they need	Increase waste
Safety first	Reduce private spaces
Cost-effective evaluations	Yield to popular opinion
Have an overall strategy in the beginning	Make choices without consulting "green" experts
Rewrite procedures that don't comply with "green"	Jeopardize quality of daily operations
Recover solvents	Use closed-mind attitudes
Reduce demand first	Ignore building codes
Recycle	Overly limit utilities
Accept change in what your lab can become	Cut corners on critical specifications
Keep things simple and flexible	Use complex systems that will be abandoned later
Provide infrastructe appropriate for occupants	Force standards that don't relate to the science

Passive Design Concepts

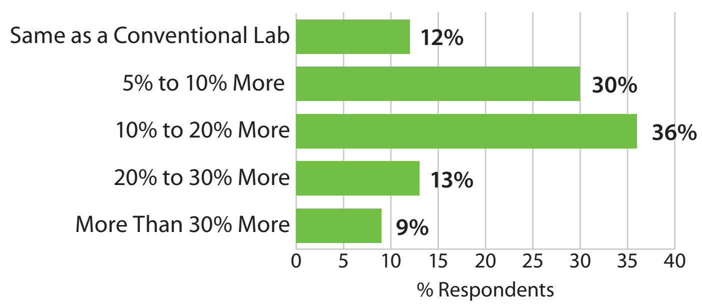
One of the comments from a survey respondent for this sustainability noted that their recommendation in creating a sustainable research lab was to go after the "low-hanging fruit" first. These are generally the lowest cost options, and generally the most successful. They're also generally passive design concepts. They often don't require any additional equipment or system support, include no mechanical systems, need little or no maintenance and often have long service lifetimes.

For energy, passive solar designs refer to the use of solar energy for the heating and cooling of lab workspaces. In these approaches, the building itself takes advantage of natural energy characteristics in construction materials and air created by exposure to the sun. Passive energy systems for labs include operable windows, thermal mass, thermal chimneys, shading devices, super-insulation and wing walls. Designs that take advantage of these concepts are based on an understanding of the building site's wind patterns, terrain, vegetation and solar exposure.

Lab Equipment Concepts

While a research lab is being built, lab planners should take into account the impact that the lab equipment and instrumentation have on the overall sustainability of the lab once they are installed. There are a number of instruments, equipment and materials that can impact the sustainability of the lab. From an energy-efficiency standpoint, the purchase of energy-efficient equipment is the most logical choice, just like the purchase of Energy Star consumer appliances is the logical choice to reduce electrical energy usage in the home. Large consumers of energy in the lab—outside of the large energy hog fume hoods—include heating and chilling systems, such as freezers, refrigerators, liquid handling chillers, ovens and furnaces. These are the

Cost of a "Green Lab"



most logical choices to consider first when looking to minimize electrical energy use, while reducing their heat-generating sources as well. Energy savings seen on new systems in these areas will outperform the energy savings realized from smaller energy-consuming devices, such as spectrometers and chromatography systems.

Looking at systems that researchers have already installed in their labs for energy conservation and sustainability programs, nearly two-thirds of the respondents to a recent Advantage Business Media survey indicated that they had installed Energy Star equipment, heat pumps and advanced glazing systems. About half of the respondents indicated that they had already installed active lab monitoring systems, low occupancy sensors, advanced boiler systems and external sun shades. Relatively few survey respondents had installed vegetated "green" roof systems (20%) and co-generation systems (14%). The level of cost savings from these energy sustainability programs was estimated to average about 7%, with about 6% of the survey respondents stating that they saw more than 15% cost savings.

The use of non-toxic chemicals in the research lab is also

Do Sustainable Technologies Affect Lab Research?

Yes – 41%	No – 59%
Requires purchase of new equipment	Only initially for training personnel
Budgetary adjustments need to be made	May require adjustment of lab procedures
Funds are now required elsewhere	Not much if you get buy-in
Increased daylighting can affect lab productivity	Not if we can move from section to section during construction
Only if the design has compromises	Complicated lighting control yes, but not the research
New technology not accepted that compromises the research	Might improve research with loss of electrical "noise"
Have to change lab protocols	Improved marketing procedures
Can affect all lab systems	Involved in sustainable materials research

a strong pro-sustainability application. This is especially relevant in easily changeable areas such as for cleaning, washing and sterilization applications. This may not always be a simple option for established chemical procedures where the desired chemical reactions rely on specific chemicals and compounds.

The use of automation systems within research labs can also be considered as a sustainability operation from a number of different aspects. First, it reduces the manpower required to perform a specific operation, making these operations more repeatable, more reliable and less prone to repeatability concerns. The use of automated systems also controls more precisely the amount of chemicals and materials used in a procedure and can reduce the overall amount used. The energy used for each manual lab operation can also be minimized with automated systems, but mostly is minor.

The use of a laboratory information management system (LIMS), like its design and construction counterpart, BIM, can also be considered a sustainable operation due to the optimization processes and procedures it provides for lab researchers. LIMS software gives researchers the ability to track and control the flow of samples and materials through the lab and identify areas where that may not be optimized from an energy-usage or chemical optimization standpoint.

Waste Management

The new LEED v4 guidelines specifically require that construction and demolition waste management plans be es-

What Budget Trade-offs Can You Consider in Designing a "Green" Lab?

New fume hood controls mean downtime for R&D, which will reduce worker efficiency for a while.
Up-front cost increase in exchange for lower operating costs.
More automated systems to reduce *in situ* lab personnel and hence lighting, heating, etc.
Not putting fume hoods in every lab.
Smaller infrastructure for better technology.
Across the company commitment to save money in all aspects of business operations.
Reduce lab size to increase sustainability.
Scale back on purchasing timelines.
Smaller chemical purchases resulting in less waste.
Purchase washable glassware instead of disposable plasticware.
Increase operational efficiency with reduced employee hours

tablished for a new construction lab facility. There also are additional LEED credits provided for the implementation of those plans. Once again, the actual operation of the sustainable research lab should have plans established beforehand for managing the waste generated within the lab. This should include systems for recycling solids and chemicals, utilization of green cleaners and solvents, acceptable and safe waste treatment processes, sustainable washing systems and non-polluting incineration techniques and systems.

Studies on the effect of implementing mostly simple sustainable waste management systems within the research lab have found that overall waste can be reduced by up to 50%, with an associated 40% reduction of the required energy use. Operating costs from these systems can also be reduced by up to a third, however, in some cases, the operating costs can be increased by more than 10% with their use. The studies also found that researcher productivity can be improved by up to 20% for waste management issues.

New versus Renovated

So what are the sustainability-based differences between building a new "green" research lab and renovating an existing lab to "green" status? We asked the readers of *R&D Magazine* and *Laboratory Design Newsletter* with the following responses.

"Building a new 'green' research lab allows architects and engineers to design and customize the lab to whatever level they desire," says one lab manager. "However, renovating an existing research lab to a 'green' lab status allows them to improve their lab energy efficiency and usage without moving to a new work location, while reducing the waste created by tearing down the existing building for the sake of building a new 'green' lab."

The downtime associated with renovations was noted by several respondents, which introduces critical productivity and overall product development issues. The comparatively short time required to move to a new facility would be much preferred.

"Ground-up construction of a new facility allows for better flexibility for building a high-performance envelope and integrating new MEP (mechanical, electrical and plumbing) systems," says another lab manager. "Renovation to a 'green' status is, of course, sustainable too, but it's not as flexible for incorporating 'green' initiatives."

Differences in costs between the two choices was also noted with many stating that they might not be able to reach the goals of a "green" lab without considerable costs and work disruptions—these would be easier to achieve when starting from scratch.

New construction can be a lower cost choice, they commented, as energy efficiency can be built into the structure—if appropriate architects and engineers are employed. "This is like buying a new car equipped with air conditioning, as opposed to adding those devices to your old car," says a respondent. Renovations may be constrained by an existing building infrastructure that can't be easily changed, so that you might not be able to make your plan as "green" as you would like.

What's Involved in Designing and Building a "Green" Lab?

Review specs of lab equipment, appliances and resources to minimize energy use and generation of environmentally undesirable chemicals.
Proper assessment of lab needs, while planning for different possible uses in the future. Maximum sustainability designs can make changing the space nearly impossible for future inhabitants.
"Green" starts from the first day of planning, how the building is oriented on the site, meeting all the codes and standards and balancing that with lab safety and functionality.
Keeping building costs down, creating a safe and pleasant place to work, making sure that the building is in compliance with work standards and reliable products are used.
It needs to be a holistic approach, not just hitting items on a LEED checklist; all systems need to be studied and related to each other.
An understanding of specific lab needs that can be matched to appropriate "green" solutions. Scientific labs for biology and chemistry don't have the same requirements.

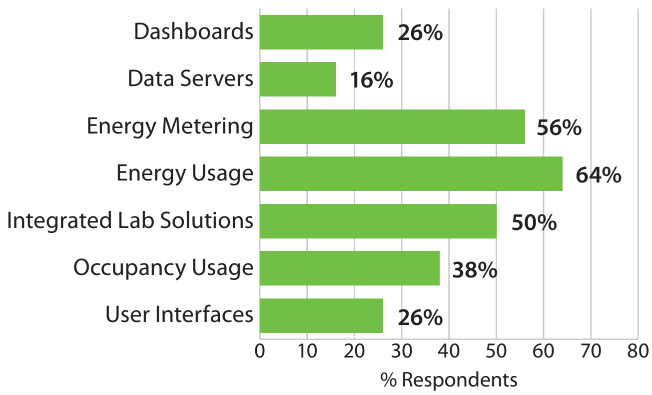
Renovation contraints focus the mind and the designer, says one respondent. "We review at a finer detail all the decisions in a renovation and then balance them with the payback."

Control and Monitoring

Measuring sustainable systems is essential to ensure the designs are working.

Taking a cue from basic management practices, the adage that you can't control or manage what you don't measure or monitor is just as true in sustainability applications as it is in human relations. All the design efforts created by the architects and engineers for a sustainable research lab structure can be wasted if monitoring and control systems aren't put in place to ensure that the designed performance characteristics are maintained. And for all the areas mentioned in this report that contribute to creating a sustainable research lab, there are numerous monitoring and control systems that can be installed to ensure that compliance.

Technologies for Monitoring "Green"



The new LEED v4 actually lists more monitoring systems as essential components for creating a certified sustainable lab structure than the previous version (LEED 2009). These include Building Level Water Metering (now a required category), Water Metering (concepts that go beyond the basic level) and Advanced Energy Metering. Of course, most of the other LEED v4 categories also have their basis in directly measurable and controllable concepts that include the management of energy, air quality, temperature, cooling (new), acoustics (new), lighting (indoor and outdoor), lighting pollution (new), various materials, water (indoor and outdoor), waste, recycling and refrigerants (new), among others.

Building Automation Systems

To maintain the sustainability designed for research labs, most larger organizations rely on building automation systems (BAS) for their energy, air and water conservation characteristics. These software-based systems often utilize leading-edge wireless systems based on IEEE 802.11 (Wi-Fi)-based technologies. The BAS system is fed by output from a variety of sensors including those for temperature, air quality, humidity, pressure and whatever specialty measurement is desired by the lab planners and designers. These sensors can be placed in multiple and various types of locations including indoor, outdoor and in ducts or pipes. Standard air quality sensors are available for carbon dioxide, volatile organic carbon (VOC) contents and others on demand.

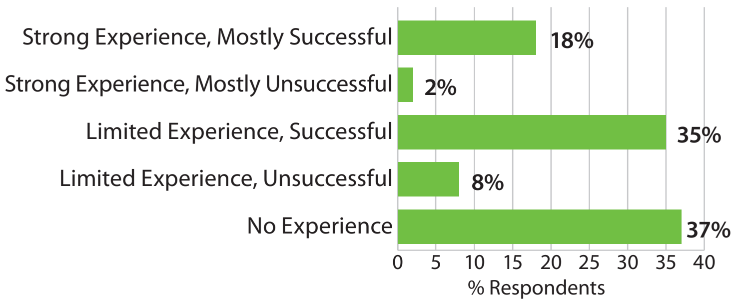
Lighting control signals can also be output from the BAS to provide the specific lighting levels needed for the research lab applications. All of these can be controlled from a single controller.

Post-processing output from the BAS can be used to

What Do You Do Differently In a Sustainably Designed Research Lab?

Constant evaluation and future planning, sometimes daily.
In sustainable research, lab equipment must be free from pollution.
We work in smaller areas with minimum systems in operation and we follow a strict regimen of not misusing lab rules.
More environmentally and sustainability-oriented decisions have to be considered.
Reduction or elimination of harmful substances and waste.
We've taken steps to eliminate bulk chemicals and reagents and manage projects so that testing and production are done with advanced planning on the amount of chemicals required, which has cut lab packs and disposal costs significantly.
Constant thinking about energy, hazardous waste and safer procedures.
Common sense things, like turning things off.
Use products that can be easily replaced because of their composition, such as bamboo without depleting the Earth's stock.
Require re-certification/re-education of professionals so that they can learn and begin to trust new technologies.
Application of solar technologies in the design phase.
More conferencing and coordination with owner and other design team members. Increased focus on designing toward energy savings.
Elimination of hazardous chemicals and generation of green tests, even though more complex.
Include all available design options that promote sustainability into the programming process so that there is consensus among lab users.

Success of "Green" Lab Projects



drive various actuators that are used to quickly operate dampers for supply or exhaust ducts, constant or variable volume devices, fume hoods, sun shades or security access points. These are available in all types of configurations; in linear, rotary and pneumatic actuating forms and from a large number of suppliers. They're also available for use on UL-listed smoke control dampers and combination fire/smoke-rated dampers. Traditional electronic and pneumatic thermostats can also provide accurate and reliable temperature control solutions for ducted air, hydronic, fan-coil units and heat pump applications.

Measurements

Metering or monitoring should be performed on all energy and utility-related devices within the research lab. This includes primary electricity sources, natural gas, water, steam, hot and cold water sources, chilled water sources and condenser water. The electrical demand for all HVAC (heating, ventilation and air conditioning) systems should be monitored, along with the fuel supplies for each, such as fuel oil, natural gas or electricity. For heated or chilled supplies, the supply and return temperatures of the liquids/gases should be measured, along with the flow rates and electrical usage.

All water supplies should be monitored, such as those for pure lab water systems, irrigation, personal hygiene, glassware washers, vivarium cage washers, make-up systems for aquatic tanks and even sprinkler systems.

The measurement points for these systems should provide enough information to the BAS to support verification of the sustainable design features. Whole building energy modeling should be performed as early in the construction phase as possible to analyze and understand the exact energy and water consumption data points. Specific monitoring intervals in the operational phases should be predetermined and agreed upon by all design and construction personnel. Continuous real-time measurements may not always be necessary to ensure sustainable operation. In these cases, the time interval between measurements will need to be agreed upon so that an average energy and resource usage can be reliably determined that meets the sustainability criteria.

It's important that baseline "non-sustainable" energy and water use values be obtained so that the sustainable feature implementations can be compared and evaluated to that baseline data. The overall measurement criteria, measuring specifications and measurement device characteristics should be documented into a plan to understand and confirm the predicted system performance created in the initial design.

Sensors

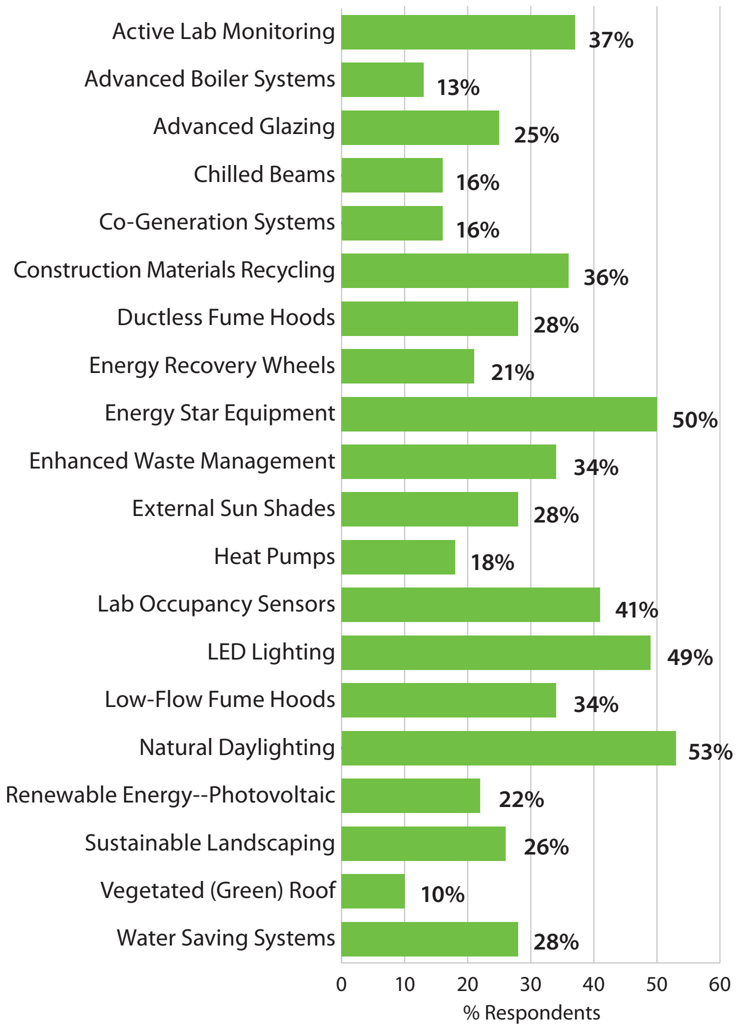
New sensors are constantly being developed for specialty research lab applications, often by students in academia. Students at the Univ. of Washington, Seattle, for example, in the Ubicomp Lab created specific devices for sustainability sensing. Their electrical device energy usage with a single plug-in sensor device, or ElectriSense, provides information to a whole home (or research lab) by determining which electrical appliances are on and off.

How Do You Know You've Created the Best "Green" Lab?

The system has to be verified with an outside consultant who is an expert in "green" energy systems, and you can also monitor the energy bills.
Measuring energy usage and user satisfaction over time—1 to 3 years.
There is no "best" for all circumstances, but it can be best for the organization at the time.
Best can be making the best "green" decisions with the available budget. It's also best if everyone knows about it so they can tell the "green" story of the company.
Meeting or exceeding specified targets/goals.
Lower energy use/ft^2 and fewer people/sample running samples would be 'better'.
Meeting the expected LEED certification level and seeing reduced energy costs compared to older labs with similar capabilities.
Increased throughput and productivity, reduced operational expenses and reduced waste generation.
Examining survey results by energy and "green" consultants and/or government agencies.
Net-zero energy.
A reduction of at least 30% in per square foot energy use.

Their GasSense device is similarly a single point-of-use sensor for determining the natural gas activity throughout the home (or research lab). Another device is their WAT-TR, which provides self-powered wireless sensing of water activity in the home (or research lab). Obviously, these are non-commercial devices without a history of reliability testing, but they do indicate a level of sophistication that sensors are approaching.

Do You Have Experience in Sustainable Lab Design?



Dashboard Control Centers

Users often interface with a BAS through an electronic display or dashboard system similar to the dashboard in an automobile. This display provides real-time utility data for monitoring all types of material consumption and energy usage. It visually provides the user with an awareness of the research lab's green initiatives, energy conservation status and tips/guides on potentially making adjustments to the overall system operation. These dashboard interfaces are generally customized for each application and can simultaneously monitor thousands of temperatures, pressures and flows at the various research lab locations.

Safety and security systems must be built into these BAS systems with audible alarms, computer-based text or email, cellular phone paging or a combination of all these. Alarms may be sent when a predetermined threshold is exceeded, in the event of power failures, power spikes or intruder notifications. Common alarms can be sent for out-of-range temperatures, pressures, biological/chemical excursions or specific or multiple component failures.

Customized dashboard displays are created to provide convenient access to important information and analytics regarding the sustainability performance of the research lab. The dashboard often displays cumulative metered information in a graphical manner that reveals trends, spikes, out-of-range measurements or any other information that might be of value to the observer. Often, drill-down data is easily accessible for any specific data point. These dashboards are often Web-based, making them accessible through a corporate Internet or remotely, and even on a mobile device through a custom application.

Fume Hoods

Traditional fume hood systems are the single largest consumer of energy in the research lab. Monitoring their performance requires a combination of the fume hood airflow control equipment, fume hood exhaust systems, HVAC system controls for the research lab housing the fume hood, fume hood sash opening position measurement devices and lab occupancy. The sustainable control of a fume hood is complex, but becomes even more complex when there are several hundreds of these devices in one research lab, especially when you consider that the overall function of these devices is to protect the user from potentially hazardous fumes. Most fires, explosions and accidents within research labs are associated with fume hoods, so the last thing that designers want to do is compromise the safety aspects of these devices for the sake of saving some amount of energy costs. Automatic sash closure devices (closing the sash when not in use) have been found the safest and most efficient sustainability device for these systems.

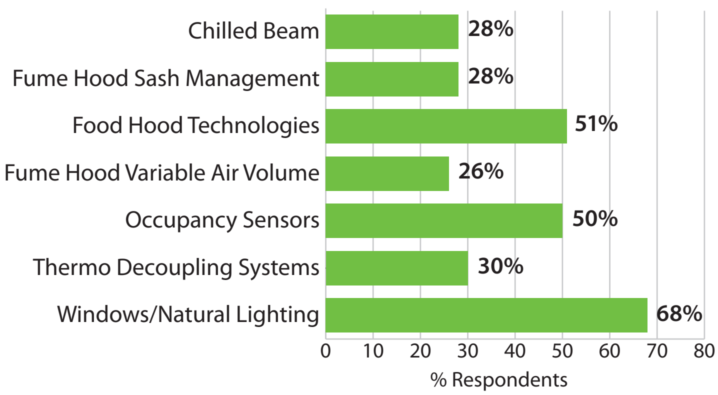
Ductless fume hoods offer the greatest opportunity to reduce energy requirements—often more than 60%—by eliminating the heated/cooled air that is exhausted from the lab and the requirement for make-up air. Ductless fume hood manufacturers claim to handle most of the chemical listed in the NIOSH Pocket Guide and, where low volumes of known chemical reactions are present, can provide a safe working environment by meeting/exceeding most lab fume hood standards. According to the Univ. of California-Irvine Environmental Health & Safety guidelines, ductless fume hood limitations, however, include use with consistent processes involving small quantities of a fixed group of known (not synthesized) chemicals; only low-hazard, non-carcinogens; non-reactive pryophorics, highly toxic chemicals or radionuclides may be used; no flammable chemicals in quantities that exceed LEL may be used; and fume hood control must be verified via full ASHRAE 110 testing. Additionally, a feasibility study should be conducted by the manufacturer to determine whether the ductless fume hood is appropriate for UCI's intended use.

Changes and Trends

New standards are driving sustainable technologies for the future.

The latest update seen in LEED v4, released in November 2013, provides a small glimpse of the expected changes in where sustainability efforts will be focused over the next several years. While some of the LEED certification changes are a little bit more of the same, just reworded and retitled, changes such as the holistic approach to materials analyses, lifecycle considerations, multiple metering (monitoring) requirements and acoustics performance establish new challenges for submitters.

Technologies Found in a "Green Lab"



Numerous LEED v4 Gold and Platinum pre-certification awards have already been obtained for several projects. Pre-certification has been allowed for LEED v4 in attempts by the U.S. Green Building Council (USGBC) to convert applicants over from LEED 2009, for which applications will continue to be accepted through June 2015 (applications will be accepted for either version during this period). The fact that LEED v4 has been released with significant updates and is supported internationally will surely continue to build its reputation for being an international sustainable building construction standard.

The current National Building Information Modeling (BIM) Standard Version 2 was released in May 2012, with 27 Version 3 updates voted on and approved this past March. The V3 updates include more detailed information on HVAC, electrical, plumbing, lifecycle, materials and other specific and general topics. The scheduled release of NBIM-US V3 is in the Fall of 2014. Most foreign countries (such as the U.K., Ireland, Canada, South Korea, Australia and New Zealand) generally use new NBIM-US updates as the basis for their own standards. Each nation adds more content as needed and share their updates back in the U.S.—these include translations, conversions into metric and various equipment-specific templates.

NBIM-US is an initiative of the private, non-profit National Institute of Building Sciences, Washington, D.C. This organization also launched the 2012 Vision Task Force (VTF) in 2013 to focus on defining, forecasting and projecting the future of the building industry to gain insights into what the NBIM-US will need to support that future. The initial effort of the 2021 VTF was to collect essays from specific subject matter experts about the nature of their role, profession or industry as they expect it to be in 10 years. Those essays are now posted on their Website, www.nationalbimstandard.org/vision2021.

Academic Starts

About 60% of U.S. basic research, or $50 billion, is performed in academic institutions, with nearly $63 billion over-

What New Sustainable Lab Design and Construction Technologies Have You Seen?

Automation in analyzers and instruments with ease of operations and quickness in reporting
LED lighting; external slats above the windows for seasonal sunlight control
Waste to energy, co-generation
Smart lighting systems
Chemical sensor system to manage air change rates more efficiently
Chilled beams
Energy recovery wheels and "green" rooftop systems
Solar panel renewable energy systems
Lower cost photovoltaic cells
Solvent recycling systems
Central chemical waste recycling and reduction
Modular construction with "green" materials and smart controls for heating and lighting
Integration of sustainable lab design features into STEM course curricula as part of science on display
New materials for lab furniture
Ductless fume hoods
Retrofitting our existing facility to LEED Gold
Energy Star freezers
Net-Zero Energy Lab at Craig Venter Institute
Power electronics that are pollution free, cost effective and more reliable
Flexible design, daylighting and heat recovery strategies
Video conferencing connectivity

What Should Be Done to Promote Sustainable Lab Design and Construction?

Improve the efficacy of rules —Many regulations are based on incorrect assumptions and don't make sense.
Designs first need to be realized where the technology will be useful and not affect lab productivity.
All building materials should be at LEED levels so designers don't have to work so hard to get and certify them.
Work more closely with actual lab occupants.
ROI justification and industry benefits need to be enhanced.
Organizations need to be forced to use lower energy fume hoods, since traditional versions use so much energy.
Verify that "savings" are real, not just chosen to "buy" LEED points.
Clear supported evidence that the addition of "green" technologies leads to long-term operational savings.
If the initial costs were to decrease, it would lead to growth.
Owners need to take the lead in having less monetary goals and more intrinsic goals.

all being spent on all R&D in academia. The vast majority of this work is performed in research labs. Academia has taken the lead in creating sustainable infrastructures, models and innovations. These initiatives will only increase in scope and become resources for technology and innovation.

The Rochester Institute of Technology (RIT), New York, for example, has established interdisciplinary sustainability programs that integrate engineering and science with economics and public policy. Among their numerous other manufacturing, engineering and technology Centers, RIT has:

- Center for Sustainable Mobility for research in transportation, renewable energy and fuel cells
- Center for Sustainable Production for enhancing the environmental and economic performance of products and processes
- The Golisano Institute for Sustainability focusing on interdisciplinary education, research and technology transfer in sustainable design, manufacturing and development
- Sustainable Energy Systems Research Group focusing on new energy and environmental systems
- Sustainable Print Systems Lab focusing on the development of sustainable designs and tools for the print industry
- Systems Modernization and Sustainment Center for developing sustainable systems for commercial and military equipment and support systems.

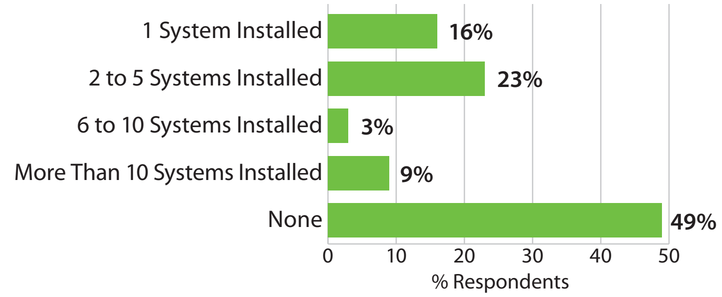
In fact, most universities now support or have multiple centers for sustainable education and research. Research labs at Harvard Univ., for example, account for nearly 50% of the energy use at the school, but only take up about 23% of the space. Resource conservation and energy efficiency in these labs are of significant importance to meeting the university's stated goal to reduce greenhouse gas emissions. Harvard has initiated numerous student and faculty-supported programs to reduce fume hood energy requirements, establish best practices for lab freezers, find chemical alternatives, implement packaging reductions and find new ways for recycling, equipment reuse, lighting reductions, general education programs and overall green lab certification programs.

The Center for Sustainable Building Research at the Univ. of Minnesota, Minneapolis, has worked with outside groups to create tools for determining lifecycle impacts on buildings including the establishment of an extensive materials database; development of decision-making tools and information for windows and glazing systems; and assisting in the establishment of programs for local communities on sustainable building designs.

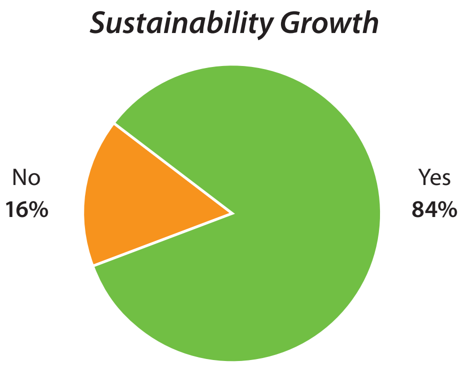
Government Support

The U.S. Dept. of Energy (DOE) is obviously a big supporter of sustainable designs through programs at its national labs. The Lawrence Berkeley National Laboratory, California, in addition to its traditional sustainability and energy-efficiency technology development programs, has taken steps to reduce water use in response to the extreme drought conditions on the West Coast and to meet long-term water conservation goals. Sustainability officers at the lab have developed a Lab Water Action Plan that monitors and addresses water use on a daily basis, irrigation systems, fixture retrofits, waste issues, cooling tower operation, overall water-related energy requirements and even food consumption.

Level of Installed Sustainable Systems



The DOE's National Renewable Energy Laboratory (NREL), Golden, Colo., has as its mission the development of enhanced energy and sustainability technologies from the development of new highly efficient photovoltaics and wind-generating turbines to the establishment of state-of-the-art research lab facilities. NREL's Energy Systems Integration Facility (ESIF) is the latest example of these efforts. ESIF is *R&D Magazine*'s 2014 Laboratory of the Year award winner for its engineering, technology, planning and program development. A LEED 2009 Platinum certified facility, ESIF optimizes the design and performance of electrical, thermal and fuel systems at different and interrelated scales, ranging from homes and businesses to communities and



cities and even on to regional and national infrastructures. ESIF sets standards for sustainable development that are likely to be integrated and implemented in numerous other sustainable research labs.

Industrial Support

LEED 2009 Platinum certification is not limited to academic and government facilities. The J. Craig Venter Institute (JVCI) located on the Univ. of California, San Diego, campus has received the Platinum award for its combination of numerous sustainable features. Touted as the first carbon-neutral, net-zero energy lab, the 44,600-ft^2 facility features wet and dry labs, offices and conference spaces all planned to foster collaboration. Reducing energy use within the lab is just one aspect of its design. From numerous water-saving features to photovoltaic panels to the inclusion of induction beams and an intelligent building system, this lab structure makes people immediately aware of their environment. Other sustainable design elements include: green roofs, recycled content, rainwater harvesting, use of regional materials, native low-water landscaping, wind and PV alternative renewable energy sources, natural daylighting and views, natural ventilation and passive cooling, on-site treatment and reuse of wastewater and Forest Stewardship Council (FSC)-certified wood.

One design feature for the JVCI was to locate the computational labs and other non-lab spaces in one wing and wet labs in the other wing to optimize the overall mechanical system. This led to two independent HVAC solutions—single-pass air with heat recovery in the wet labs and more passive heating and cooling in the dry spaces, taking advantage of the mostly benign Southern California climate. The wings are oriented east-west to minimize solar exposures, and lab support spaces are located to the south to reduce solar cooling loads.

In addition to these reduced energy-consumption designs, creating flexible spaces that don't require extensive renovation can reduce the embedded energy of the construction materials over the lifecycle of the building. The San Diego JVCI took advantage of the established JVCI in Rockville, Md. To properly size electrical and HVAC systems for the West Coast facility, the Institute's East Coast labs were metered, allowing the design teams to design to actual loads.

The sustainability features created for the West Coast JCVI are being used by the facility planner, ZGF Architects, as an integrated design to advance innovative sustainability features on a new generation of private and government-funded projects with limited budgets and strong sustainability requirements.

Resources

American Institute of Architects (AIA)
www.aia.org

American Institute of Steel Construction (AISC)
www.aisc.org

Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC)
www.aaalac.org

Building Research Establishment Environmental Assessment Method (BREEAM)
www.breeam.org

Canada Green Building Council
www.cagbc.org

Centers for Disease Control and Prevention (CDC)
National Institute for Occupational Safety and Health (NIOSH)
www.cdc.gov/niosh

Center for the Built Environment
www.cbe.berkeley.edu

Energy Star
www.energystar.gov

Green Building Initiative
www.thegbi.org

J. Craig Venter Institute
www.jcvi.org

KlingStubbins – Sustainable Design of Research Laboratories
www.klingstubbins.com

Laboratory Design Newsletter
www.labdesignnews.com

National Institute of Building Sciences (NIBS)
Sustainable Buildings Industry Council (SBIC)
www.nibs.org

NIBS 2021 Vision Task Force
NIBS National BIM Standard US Version 2
www.nationalbimstandard.org

R&D Magazine
www.rdmag.com

Siemens Building Technologies
www.buildingtechnologies.siemens.com

Rochester Institute of Technology
www.rit.edu/research/sustainability_labs.php

Whole Building Design Guide – A Program of the NIBS
www.wbdg.org

U.S. Department of Energy (DOE)
www.energy.gov

National Renewable Energy Laboratory
www.nrel.gov

Office of Energy Efficiency and Renewable Energy
www.eere.energy.gov

Office of Health, Safety & Security
www.hss.energy.gov

U.S. Environmental Protection Agency (EPA)
www.epa.gov

Labs and Research Centers
www.epa.gov/aboutepa/index.html#labs

U.S. General Services Administration (GSA)
www.gsa.gov

U.S. Green Building Council (USGBC)
www.usgbc.org

Green Building Certification Institute (GBCI)
www.gbci.org