Sustainable Design of Research Laboratories

PLANNING, DESIGN, AND OPERATION

KLING STUBBINS

with a foreword by
William McDonough, FAIA

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FOREWORD

People have come to realize that it is buildings, not just transportation, manufacturing, and forest loss, that produce a lion's share of energy consumption, carbon concerns, and material flows. It follows that if we want to get to the heart of one of the biggest creative opportunities of our time and find the most creative solutions, our efforts can include a close examination of how buildings are designed, constructed, and maintained, and even how they are deconstructed and reconstructured over many useful lifespans.

Of all building types, research laboratories are some of the most resource-intensive. They use an enormous amount of energy to heat, cool, and power sophisticated equipment; they produce by far the largest volume of emissions in terms of exhaust air; and they use a lot of material. By finding ways to design and engineer research laboratories more efficiently, effectively, and sustainably, the lessons learned easily can be adapted to the design of other building types and other industries.

That's what makes this book, *Sustainable Design of Research Laboratories*, indispensable to understanding recent advances in the field. It's a compilation of tools and techniques from a wide variety of sources about what works, and what doesn't, in the search for sustainable lab design. It will open new doors—and change attitudes—about what's possible, and will point the way to significant reductions in energy use and carbon emissions while actually promoting a healthier workplace for staff. Because lab buildings typically operate on a 24/7 basis, every improvement can make an enormous difference.

In a way, research labs can be seen as some of the most technically sophisticated architecture that our society creates. They embody in function, style, and structure the culture of our age, symbolizing our scientific capacity to explore and discover new ways of doing things. As we enter a new age of a sustaining and self-renewing economy, it's important that we get it right and a sustaining design agenda is one of the best gifts that we can bestow upon the next generation; the consequences will be felt for decades to come. It's a long-term journey that starts with steps in the right direction, and this book will provide a valuable compass.

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chapter 1 Introduction

Courtesy of KlingStubbins.
Photography by Ron Solomon—Baltimore © 2008.

> *If our designs . . . are to be correct, we must at the outset take note of the countries and climates in which they are built. This is because one part of the earth is directly under the sun's course, another is far away from it, while another lies midway between these two . . .*
>
> —Vitruvius[1]

Core Principles

While the terms "green building" and "sustainability" are relatively recent, the idea of sustainable design has been an intrinsic part of building design and operation since the beginning of organized civilization. Because there were no mechanical and electrical systems, early buildings needed to be designed to carefully take advantage of the environment and climate of the places they were constructed. They needed to be sited to catch prevailing winds, and to take advantage of natural shading to stay cool in warmer months. Organizing the functions of the buildings so they would receive sunlight as it moved through the sky was important before there was easy access to electric lighting. The walls of the buildings needed to be constructed to protect against temperature changes throughout the year. Before global transportation networks, it was critical to build out of materials that could be sourced locally, would last a long time, and could be easily removed and disposed of with minimal effort. It took a great deal of effort to find clean water, and fuel for heating (wood, peat, and coal), so these resources were carefully managed. In short, there was no such thing as building "green," buildings had to be able to mitigate local environmental conditions and efficiently make use of the materials and resources close at hand.

With the advent of industrialization, another issue came into the public eye—the connection between living and working conditions and human health. Increasing occupant access to light and fresh air was proposed to alleviate these challenging conditions. The link between buildings and the occupants' health and safety has been an important part of public regulation of buildings ever since.

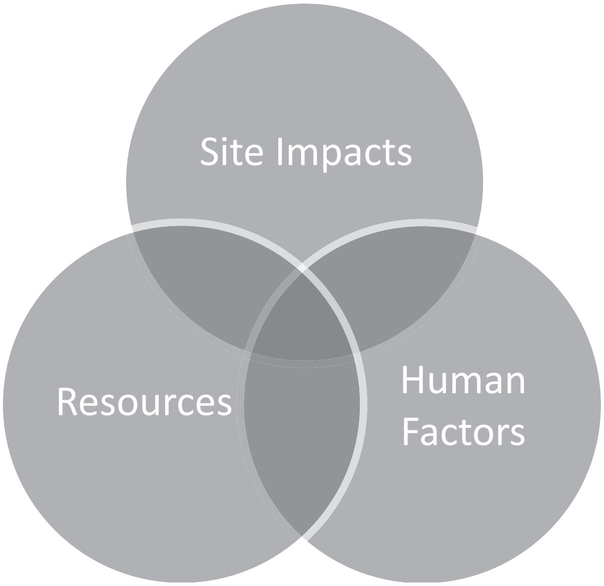
The connection among buildings, resources, and human health as a focus of sustainable design makes a strong case for sustainability in laboratory buildings. The scientific mission and organizational goals of most laboratory users are a natural fit for sustainability. Research scientists are striving to find out more about how things work in the world, biologically, physically, chemically, and environmentally. Sustainability is focused on maintaining a balance between what our buildings need in order to support us, and what that means for the world around us. Intrinsic to that is how we make and operate the building, and how the building affects us as we occupy it.

This book will focus on how laboratory facilities can be more sustainable in design, construction, and operation. We will look at what makes buildings more sustainable, and focus on how laboratory facilities differ from other buildings to get an overall look at how to design and operate a sustainable lab building. While lab buildings offer challenges to green building goals, there's also the potential for great impact by making these buildings perform optimally. If lab buildings use five to ten times more energy than office buildings,[2] even a modest percentage reduction means a large amount of energy saved. Over the last ten years or so, many groups have begun to refer to "green" buildings as "high performance" buildings, to emphasize that the goal is to find a way to make these buildings perform in a highly efficient fashion. While part of green building is conservation—reducing what we need—another aspect of it involves a strong focus on optimization—making sure we deliver what we need in the most efficient manner possible. For example, a great deal of energy can be saved by changing the temperature setpoints, i.e., turning the thermostats up in the summer, and down in the winter. This is conservation—changing what we ask our buildings to do, and changing **our** behavior. Optimization means finding a more efficient way to make the building cool in the summer and warm in the winter. True high-performance building design counts on **both** conservation and optimization, and for a laboratory building, it is critical to make sure that this does not threaten the research objectives. While the process is the same for lab buildings and nonlab buildings, the decisions and results will be different.

There are many different factors involved in high-performance building design covering a broad range of different aspects of the design and operation process. In reality, the concepts are very simple; there are three main ways that a building impacts the environment: site impacts, resource use, and human factors.

Site Impacts

The broadest category is the site; this includes site selection, site design, and site connection with the community for transportation, infrastructure, and waste. Possibly the biggest impact is determined by which site the lab building will be built on. Should it be a new building, or a renovation of an existing building? Should it be in a developed area, near existing infrastructure, or an undeveloped greenfield site? Should it



Although there are many different strategies to pursue sustainability, most can be ascribed to three main categories: minimizing site impacts, reducing resource use, and improved human factors. *Image courtesy of KlingStubbins.*

be near potential employees or occupants? Each of these questions has a big impact on the project, and for each, laboratories often require different answers than other types of buildings. For example, while it is relatively easy to adapt a building to office use, only certain buildings can be renovated into ventilation-driven labs, based on the infrastructure needs.

Once the project site has been selected, the integration of the building with the site can significantly reduce its impact. The project can minimize changes to the natural hydrology of the site and can work to minimize the flows of water and waste into existing ground sources and waste streams. The project can minimize the amount of impervious materials added to a site, which will reduce runoff. The project can also put in place natural controls and features to treat runoff and waste on site rather than letting it contribute to stormwater system overloads of volume and suspended solids. Laboratories, depending on the type of research being done, are likely to have significantly more waste products, and care must be taken to manage, remediate, and treat liquid and airborne wastes to minimize impacts on the surrounding community. Care must be taken to ensure that waste stacks are modeled and monitored to prevent laboratory exhaust from reentrainment at building air intakes.

Resources

The second category of impact for a project is resources: water, energy, and materials. We'll focus on a number of different strategies, but they all really

For this detailed study of wind-wake analysis at the University of Colorado Denver's new Research 1 and 2 complexes in Aurora, Colorado, computer simulation or physical wind-tunnel testing can ensure that exhaust streams will be safely dispersed and diluted before getting to nearby buildings, outdoor occupant areas, or air intake louvers in the vicinity. *Image courtesy of RWDI.*

boil down to three main concepts: reduce the amount of resources needed, find a more efficient way to deliver the resources, and use alternative sources for these resources. Careful attention to these three aspects during design, construction, and ongoing building operation is necessary to reduce the overall "environmental footprint" of the project. For each of these three categories of resource use, the research requirements and criteria will affect which strategies are possible for each project.

Water

The supply of safe and plentiful drinking water is critical to human survival. In many parts of the world, the available supply of potable water is insufficient. The amount of energy spent to transport water from one place to another is significant. Studies have shown that in some areas, the energy used to transport water is a larger proportion of the carbon footprint than localized energy use. Water tables are dropping in many parts of the United States, and in many coastal regions saltwater levels are encroaching on former freshwater aquifers, rendering them useless as potable water sources. Laboratory facilities are significant water users for both sanitary and process uses. Sustainable strategies for water reduction have focused on two main areas—reducing the amount of water needed by using more efficient fixtures and closed-loop systems where possible, and by using nonpotable water for as many uses as pos-

At Johnson & Johnson's Pharmaceutical Research and Development (PRD) Drug Discovery Laboratory, Phase II building in La Jolla, California, several water conservation measures were undertaken. In addition to high-efficiency sanitary systems, the project employed a cooling coil condensate recovery system, reusing that water for cooling tower makeup water, and combining it with municipally provided reclaimed water to handle all irrigation needs with nonpotable water. The company has calculated that they save approximately one million gallons of water per year using this system. *Image courtesy of KlingStubbins. Photography © Tom Bonner 2007.*

sible. Highly efficient glasswash systems, closed-loop process chilled water systems, and use of water-free handwash stations are methods of reducing water use as required in labs. Reuse of reverse osmosis and deionized (RO/DI) reject water is another way to minimize the water waste in a laboratory facility.

Energy

Reducing the energy usage of a building is really achieved by three separate strategies, each of which works together to achieve optimal energy use. The first is **rightsizing loads**. Project design starts with assumptions about design criteria—what temperature and humidity is desired, what light level is needed, how much fresh air is needed for each space, and what amount of variability is acceptable for each of these criteria. Each of these criteria has an impact on the size of the systems designed, their cost, and the amount of energy they will use. When project criteria are challenged, internal loads on the systems are reduced. Another critical part of rightsizing the loads is to minimize any external gains and losses on the building—by studying the optimum orientation and the proper exterior building components, the project can reduce and mitigate exterior loads due to solar gain and exterior environmental factors. Insulation can be added, shading devices can be designed to reduce the solar loads on the glazed areas of the building.

The second strategy is **system selection and design.** Once the loads have been minimized, systems can be selected and designed. Often starting with lower assumed loads will mean there are more options possible for system selection and design.

The third strategy is **energy source efficiency.** Once the loads are minimized and optimal systems are designed, the team can look at ways to find cleaner sources of energy through onsite generation through renewables or co-generation, or through green power procurement. For a good example of successful energy-source efficiency implementation, see color images C-66 through C-73 of the Johnson & Johnson La Jolla, California site.

For the Smithsonian Tropical Research Institute Field Station Laboratory at Bocas del Toro in Panama, the design team first challenged criteria, divided functions to minimize loads, and created this large photovoltaic panel canopy that provides added shading and diffusion of light entering the occupied spaces below, as well as generating the majority of energy required for this laboratory facility. *Image courtesy of Kiss + Cathcart, Architects.*

Materials

There are several different ways that environmentally preferable materials can be evaluated. It is necessary to consider not just the material itself, but to factor in the overall impact over the lifecycle of its use. Environmentally speaking, the ideal material is made from raw materials that are nontoxic, plentiful, and renewable; takes very little energy to extract, formulate, and

For the Novartis Institutes for Biomedical Research 100 Tech Square project in Cambridge, Massachusetts, the team evaluated the cost over the lifespan of the flooring material and determined that the rubber flooring, although more expensive to purchase and install, would last longer and require significantly less maintenance over its service life. This was a successful "rightfit" approach to finish materials for the lab. *Image courtesy of KlingStubbins. Photography © Chun Y Lai. All Rights Reserved.*

fabricate; uses very little energy to transport and install; is extremely durable and easy to maintain; and at the end of its useful life can be recycled or reused efficiently. There are several different ways to categorize materials. Laboratory materials have some added factors, depending on the type of research being done. The materials may need to be chemically resistant, or impervious to radioactive or biological agents. Cleanability and durability under more stringent cleaning and maintenance routines are required for many lab materials. Critical to effective selection of materials is "rightsizing" the materials for the scientific requirements of the space. For example, selecting scrubbable ceiling tiles is only necessary if the ceilings are actually going to be scrubbed. For many labs, conventional office ceiling systems are perfectly acceptable, and can be made from more environmentally friendly materials.

Human Factors

People spend more than 90 percent of their time inside buildings. How the building environment impacts them plays a big part in overall satisfaction, productivity, and human health. Although sustainable materials, energy efficiency, and water consumption comprise a big part of our focus on green building, many have argued that the major way that green buildings contribute to the environment is through human factors inside the building. The major strategies that address human factors in buildings are air quality, occupant comfort, and connection with the exterior environment.

Air Quality

Although part of indoor air quality is concerned with protecting occupants from outdoor contaminants, it has been shown that contaminant levels inside buildings can be many times higher than outdoor levels. Increasing outside air quantities can help reduce contaminant levels. For lab buildings, where there are often high ventilation requirements, air quality must be controlled through careful separation of chemical uses and ventilation design. Use of low-volatile organic compound (VOC) materials is important to minimize sources of contaminants in buildings, and many conventional laboratory materials—epoxy flooring, adhesives, and epoxy paints—are now formulated with low VOC levels.

Occupant Comfort

There are several factors contributing to occupant satisfaction and productivity, including lighting, glare, acoustics, and air movement. Studies have shown that the most important factor contributing to occupant satisfaction is thermal comfort. Since different people can experience the same spaces with different reports of thermal comfort, providing some level of occupant controllability or adjustability is important. This is challenging in laboratory spaces where frequently the HVAC system is closely controlled and monitored from a central building automation system. Conventional design has focused on ensuring that systems will offer consistent and even conditions. Recent studies have borne out that providing zones for occupant control is also important for thermal comfort.

Access to Environment

Another category which has been positively correlated with occupant satisfaction and productivity is visual connection to the exterior environment. Spaces lit by natural daylight have been proven to improve occupant health and satisfaction. For space where daylight penetration is not desirable or possible, views to the exterior have also been shown to correlate to occupant productivity. Providing views to the exterior requires attention to shading, since solar gains and glare can negatively impact the research objectives.

In summary, there are some special challenges in creating a sustainable laboratory building. Many labs use a lot of energy for process loads, equipment loads, computer loads, and other "plug loads." These process loads can represent a significant majority of overall building loads, and cannot necessarily be changed with current available scientific equipment. Many labs use stronger and more toxic materials for research. This means that the finishes and systems that come in contact with these materials need to be highly resistant. Many labs require tighter control of the environment for scientific purposes. Maintaining tight control of temperature, airflow, and humidity takes far more energy than in nonlab spaces, where people can tolerate a broader range of comfort factors. When the research studies require it, the tight control can reduce the ability to optimize the energy use.

At the University of California, San Diego's Leichtag Biomedical Research Building, the design team organized the overhead service and ductwork distribution to allow the ceiling to slope up to an increased head height at the exterior wall. This allows for added daylight penetration farther into the lab building. Note that there are exterior shading devices as well as frit patterns on the glazing to cut down on glare at the perimeter work areas—a "right-fit" approach to finish materials for the lab. *Image courtesy of ZGF Architects LLP. Photography © Anne Garrison.*

DESIGN AND OPERATION OF THE SUSTAINABLE LABORATORY BUILDING: Considerations and Musings

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As noted by the authors of essays and chapters in this new work, innovative new models for the design of the laboratory of the future have been emerging over the past few years. These models are expected to be able to create laboratory environments that can respond to the needs of the present while being flexible enough to accommodate the demands of the sciences of the future. These demands will influence not only industrial and government laboratories but also academic laboratories. The latter types of laboratories are very important in our discussions of industrial and government laboratories because the academic laboratory is where the scientist of the future not only receives their training but develops their skill sets, both scientific and social. Furthermore, they also develop their habits, expectations, scientific work ethic, acceptance, and tolerance to changes in their work environments.

When looking at trends in laboratory design that emerge from conferences, professional architectural journals, or even commentary on new architecture in the public media such as newspapers, it is hard to dissociate architectural design for something even as specific as a research laboratory from the concept of sustainable architecture. In this instance, as noted by J.J. Kim (National Pollution Prevention Center for Higher Education, 1998) the debate over the terms “sustainable,” “green,” or even “ecological architecture” is not terribly important. What is important is that the concept of sustainable architecture is driven by an observation patently obvious to most working scientists that there is a very important and at times intense social aspect to modern science. Even as scientific collaborations and drug discovery become virtual because of a Web 2.0 world, research laboratories will still exist. Hence, the social aspects of science will lead to the design of more social buildings to enhance and support team-based research.

However, can one go from the definition of sustainable architecture offered by the UNCED Brundtland Commission (1987)

> . . . a building “that meets the needs of contemporary society without denying future generations of the ability to meet their needs . . .”

to the design of sustainable labs? In essence, can one design a social building that is flexible in design and operations, yet fosters team-based interdisciplinary collaborative research, and is sustainable in its internal operations involving energy usage and downstream byproducts of the research process? Here, too, we need to address the byproducts and be aware of the potential downstream pollution caused by the building itself and the consequences of the science carried out in the building. Part of this concern is the ultimate awareness of the external environmental issues caused by the building and how it architecturally relates not only to the local but also to the global environment. The key to successful implementation of this concept again comes back to sustainable design.

The flexibility of the laboratory of the future is not incongruent with the above definition of sustainable architecture, and the need for social buildings that respect the local and global environment. It is how we get convergence of the two concepts that will be brought forth by the discussions herein. We need to be continuously aware of the competing logic inherent in an architectural design that is sustainable. Sustainable in that the technology we use to construct our buildings is nontoxic, participatory, and flexible. The buildings should also embody certain critical values, two of which are that they should look like the coming age and be nonhierarchical and socially cohesive (S. Moore, Univ. of Texas Center for Sustainable Development). These strategies involve many principles as outlined by J.J. Kim of the University of Michigan (1998).

One needs to think first about the economy of the resources needed to construct and operate the building. Kim thinks of a building as partly a dedicated ecosystem and as such, feels the architect should think about both the upstream flow of materials into the building during construction and the downstream flow as output from the building's ecosystem into the local and then global environment. The latter, that of downstream material flow, is perhaps one of the most nebulous to consider when thinking about sustainable design of any R&D laboratory. While we can think about designing flexibility into the laboratories, offices, and support and interaction space, it is very difficult to try to predict where the science might be directed 10 or 15 years in the future. Peter Drucker once commented, "The only thing we know about the future is that it will be different." This is, perhaps, the best way to think about strategic planning for the laboratory of the future. In essence, we must plan for events and activities to be different and be conscious of the fact that the science of the future needs to be transformational.

However, in addition to designing for science to be transformational, we also need to think even more long term. Philosophers of science in the 1960s like Thomas S. Kuhn wrote about scientific revolutions and paradigm shifts. These paradigm shifts in thought and approaches to science emerged from war efforts such as the Manhattan Project, where suddenly the government and private industry became the primary source of financial support, and at times, the primary driver for the directions pursued by science. This influenced not only the physical sciences but also the biological sciences. Almost 50 years later, modern-day philosophers of science look not just to paradigm shifts, but also to disruptive technologies that will change the pursuit of science and remap entire fields of scientific endeavor. On the consumer side, the personal computer and the iPOD are examples of disruptive technologies that have changed how we can interact with information on a personal level. Will our labs of the future be ready for similar disruptive technologies? More importantly, will the scientists in training today be ready to interact with these disruptive technologies? Is the virtual drug discovery firm enabled by the advent of the Web 2.0 world, the disruptive technology we all hope will move fields ahead?

Again, while we now think about flexibility, does it mean that we can still design for a sustainable, environmentally friendly structure—both internally and externally? We need to be mindful now that as the science changes, the downstream material flow will most assuredly change. Sometimes the internal and external impact of that changed flow will not be predictable as the technology frequently races ahead of our understanding of its long-term consequences. One movement is attempting to gain traction in industrial and university settings by attempting to address one of the largest sources of negative internal and external environmental impacts: chemistry. This new movement has been termed "Green Chemistry."

Berkeley and colleagues (*Pharmaceutical Engineering*, March/April, 2009) have asked a very relevant question: Should the biopharm industry really be interested in green chemistry? Their very well-documented and pointed argument is that, indeed, biopharm must be interested for green chemistry is the "how" in how biopharm becomes a sustainable industry with a firm

continued

commitment to building sustainable laboratories and manufacturing sites. It is only via these sustainable facilities that biopharm is part of a healthy environment. This movement has raised the awareness of industrial and university chemists because even pursuing synthetic inorganic and organic chemistry on a small scale still results in the import and export of chemicals to buildings. These materials enter laboratory buildings in the forms of solids, gasses, and liquids, presenting both defined and undefined risks to building occupants. Management of these risks internally is readily achievable via proper building design and internal material management. However, downstream there is even more of a potential risk in that long-term environmental consequences of many of these waste and defined products have yet to be fully understood. This is of special concern to the public in areas of emerging technology such as genetically modified foods and nano particles. This should really force industrial concerns and universities concerned with sustainability to a lifecycle view for all solvents and waste streams from their facilities.

Nevertheless, green chemistry is being turned to for the opportunities it affords in reducing waste that leads to reduced operating and perhaps even maintenance costs of a sustainable laboratory. It really comes down to applying paradigms of operational excellence; activities that biopharm firms have been slow to embrace let alone act upon. Obviously, the biggest impact of green chemistry is on the manufacturing side of the equation in the production of intermediates, API, and finished pharmaceuticals because of the volume of the waste stream generated by the synthesis of these materials. How much waste is actually produced is up for conjecture, as no one knows precisely what those volumes are. However, Berkeley and colleagues estimate that worldwide it might be as much as 6.6 billion pounds produced in the manufacture of API. Add to this tonnage the chemicals that do not end up in the API and, as noted by Berkeley, the industry further encounters lost opportunity costs as well as the regulatory burdens associated with waste materials handling within buildings and subsequent disposal costs of solvents and waste byproducts. As noted by the late Senator Evertt Dirksen, “A billion here, a billion there—pretty soon it adds up to real money.”

However, even in the research lab, the tenets of green chemistry are important considerations in the discovery phase when synthetic processes are being explored and designed for scale-up to the manufacturing level. This is especially important as so many pharmaceutical chemical and even biological synthetic processes that are scaled-up consume large quantities of water. Water shortage is a critical issue worldwide as are the consequences of managing water usage and disposal in an environmentally responsible manner in a building. Hence, water usage as a facet of green chemistry is an important factor that must be considered in the sustainable design of a modern laboratory building and, again, putting material usage and operations in the context of a lifecycle analysis framework.

Couple the above concerns with the fact that we know that a typical research laboratory uses five times as much water and energy per square foot as a modern office building. Link that with some of the more reasonable requirements in designing research space and many opportunities and challenges present themselves:

- Many redundant systems, e.g., power, lighting, telecommunications;
- The requirement for 24-hour access by the scientists and critical support staff in areas such as vivariums and mechanical spaces;
- Modern research instrumentation such as NMR, Mass Spec, robotics, tissue culture incubators, etc., that produce significant quantities of heat and;
- Depending upon the nature of the science involved, there may also be a significant number of hoods (chemical and biological) that requires not only containment but also the necessity to exhaust either partially or totally to the outside environment;

- These hood and heat requirements create a very intense HVAC requirement that also include "once through air" for specialized labs (high containment) or vivariums.

If done correctly, assessing the operating requirements in a holistic manner can lead to better sustainable design that will conserve energy, water, and key consumables while improving productivity as a consequence of an improved laboratory environment.

Another principle, as noted by Kim, is the concept of thinking about the lifecycle of the design. The concept of lifecycle is a notion that is well engrained in software engineers and developers who always think about the:

- Planning Phase
- Design Phase
- System Development and Testing
- System Qualification and Commissioning
- System Operation
- System Retirement and Decommissioning

If one looks at the software lifecycle, it does not really take much imagination to replace the word "system" with "building" and apply the above phases to thinking about sustainable architectural design. There is indeed significant congruence in the phases and the sequence of events.

As more and more architecture and building operations approach the principle of being sustainable, one needs to think about the lifecycle process. This means addressing not only placing the building in the environment respectfully and responsibly, but also designing the building and operating it responsibly. What must also transpire is the need to address what will happen when it is no longer cost-effective to renovate the building or repurpose it. The concept of retirement and decommissioning is very important to sustainable architecture but not one usually given much thought. Have we chosen wisely in utilizing materials that can be recycled into the next project, or ultimately is the entire building consigned to a landfill? In looking specifically at an R&D laboratory, the ability to recycle building materials as part of being environmentally aware is affected by the nature of the science that goes on in the building. We can indeed create systems to contain toxic chemicals and biological substances, and protect the building occupants and the environment from them. However, does the way these containment systems are designed lead to long-term "corruption" of the building materials so that it can never be reused or repurposed? Do we create an even bigger problem in that many of the building components must now be treated as hazardous waste when the building is decommissioned, adding further to the closure costs. No pun intended, but that is not a sustainable scenario for the future.

The final principle that affects sustainable design as outlined by J.J. Kim is the idea of humane design. It is one that he considers perhaps the most important to the concept of sustainable design, especially as it applies to an R&D laboratory. As humans, we spend a significant percentage of our lives indoors. For scientists, this may be even more on a percentage basis than the average office occupant may. Architects have hypothesized for many years that the space we occupy influences our behaviors, feelings, thoughts, and ultimately our social interactions. Designing a building solely to address style and form making ignores

continued

modern research on social cohesion: something that is extremely important in science where interdisciplinary and collaborative research is necessary, again reinforcing the social nature of modern science.

Many R&D firms have approached the concept of collaborative research by designing space around “tribes” of scientists from multiple disciplines, all socially linked via common projects. This approach also involves flexible design, further enhancing and in some instances forcing interactions among scientists with different skill sets but all collaborating on the same research projects. Those interactions can be critical in advancing the science rather than waiting for chance encounters in breakrooms or hallways. Joan Meyers-Levy of the University of Minnesota has recently published studies that even show that the height of the ceilings in a room can negatively or positively affect how people think. Her observations on ceiling height stress how a high ceiling may actually lead room occupants to making connections that are more abstract. This could lead to better and more enriching interactions between scientists from differing disciplines such as biologists, chemists, statisticians, development pharmacists, and process chemists—all are physically co-located with the common goal of problem solving for dedicated projects.

Additionally, many studies over the years, especially in Europe, have shown the value of bringing more natural light into our work environment where conditions permit. Obviously, restrictions are present especially for specific needs such as darkened rooms, instrumentation impacted by changing light levels, or very specific vivarium requirements for defined light/dark cycles only controlled via artificial lighting. However, just as the animal occupants of vivariums need a defined light/dark light cycle, humans need natural light to help synchronize our circadian rhythms enabling us to stay awake during the day and sleep at night. Buildings, and especially labs of the past, were not designed to optimize the need for natural light. Rather, we maximized footprints with as much internal, and at times, windowless space as possible and maximum usage of corridors without natural light to enhance the movement of people and materials. However, the sustainable laboratory architecture of the future needs to factor in access to natural light wherever possible.

Circling back to our original focus on sustainable design and more importantly the humane connection, critical factors repeatedly noted in sustainable design also relate to the preservation of natural conditions surrounding the building, site planning, and ultimately how the design impacts human comfort. Affording natural light and settings have been shown to improve mental focus as noted previously. These and other design considerations could lead to better and more enriching interactions between scientists from differing disciplines such as biologists, chemists, and statisticians. Again, all parties are physically co-located and share a common goal of problem solving for dedicated projects. Putting all these concepts together, sustainable architecture should lead to an improvement in both qualitative and quantitative benefits by:

- Further enhancing the operation and maintenance of new laboratories;
- Putting the usage of material and the building into the contextual framework of a lifecycle paradigm;
- Ensuring the preservation of the natural conditions surrounding the site;
- Providing a better holistic fit for the structure and its activities in the surrounding community and environment; and
- Creating a work environment that enhances productivity and nurtures interdisciplinary and team interactions by fostering the creation of a social building.

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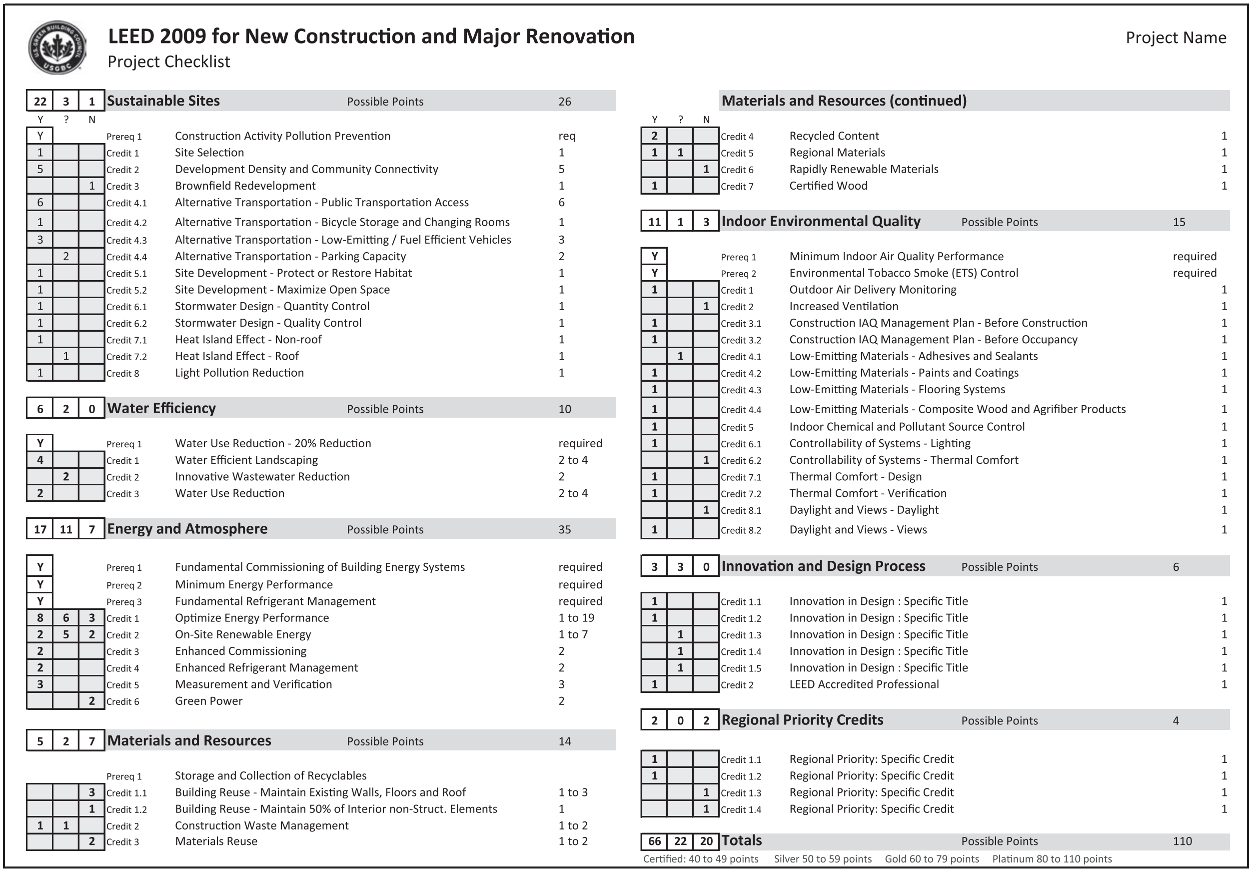
Metrics/Ratings/Scorecards—Why Use Them?

The design and construction process includes many different players. The team is made up of the owner, the design professionals, and the builders. Within each of these groups there are different stakeholders. The owner usually includes organization leadership, end users, facilities planners, facility maintenance groups, and safety officers. The design professionals include engineers, architects, interior designers, and often specialized consultants for specific areas. The construction group can include estimators, schedulers, construction subcontractors, and sometimes logisticians who focus on phasing and move planning. Within all of these different groups there are usually very different points of view about what is most important. Starting out with a clear set of metrics or goals can help all of these groups to have a common language about what strategies to pursue. It provides a single clear way to communicate between different groups—how they define energy



LEED 2009 for New Construction and Major Renovation
Project Checklist
Project Name

Y	?	N			
22	3	1	**Sustainable Sites**	Possible Points	26
Y			Prereq 1	Construction Activity Pollution Prevention	req
1			Credit 1	Site Selection	1
5			Credit 2	Development Density and Community Connectivity	5
		1	Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation - Public Transportation Access	6
1			Credit 4.2	Alternative Transportation - Bicycle Storage and Changing Rooms	1
3			Credit 4.3	Alternative Transportation - Low-Emitting / Fuel Efficient Vehicles	3
	2		Credit 4.4	Alternative Transportation - Parking Capacity	2
1			Credit 5.1	Site Development - Protect or Restore Habitat	1
1			Credit 5.2	Site Development - Maximize Open Space	1
1			Credit 6.1	Stormwater Design - Quantity Control	1
1			Credit 6.2	Stormwater Design - Quality Control	1
1			Credit 7.1	Heat Island Effect - Non-roof	1
	1		Credit 7.2	Heat Island Effect - Roof	1
1			Credit 8	Light Pollution Reduction	1
6	2	0	**Water Efficiency**	Possible Points	10
Y			Prereq 1	Water Use Reduction - 20% Reduction	required
4			Credit 1	Water Efficient Landscaping	2 to 4
	2		Credit 2	Innovative Wastewater Reduction	2
2			Credit 3	Water Use Reduction	2 to 4
17	11	7	**Energy and Atmosphere**	Possible Points	35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	required
Y			Prereq 2	Minimum Energy Performance	required
Y			Prereq 3	Fundamental Refrigerant Management	required
8	6	3	Credit 1	Optimize Energy Performance	1 to 19
2	5	2	Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
2			Credit 4	Enhanced Refrigerant Management	2
3			Credit 5	Measurement and Verification	3
		2	Credit 6	Green Power	2
5	2	7	**Materials and Resources**	Possible Points	14
			Prereq 1	Storage and Collection of Recyclables	
		3	Credit 1.1	Building Reuse - Maintain Existing Walls, Floors and Roof	1 to 3
		1	Credit 1.2	Building Reuse - Maintain 50% of Interior non-Struct. Elements	1
1	1		Credit 2	Construction Waste Management	1 to 2
		2	Credit 3	Materials Reuse	1 to 2
			Materials and Resources (continued)		
2			Credit 4	Recycled Content	1
1	1		Credit 5	Regional Materials	1
		1	Credit 6	Rapidly Renewable Materials	1
1			Credit 7	Certified Wood	1
11	1	3	**Indoor Environmental Quality**	Possible Points	15
Y			Prereq 1	Minimum Indoor Air Quality Performance	required
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	required
1			Credit 1	Outdoor Air Delivery Monitoring	1
		1	Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan - Before Construction	1
1			Credit 3.2	Construction IAQ Management Plan - Before Occupancy	1
	1		Credit 4.1	Low-Emitting Materials - Adhesives and Sealants	1
1			Credit 4.2	Low-Emitting Materials - Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials - Flooring Systems	1
1			Credit 4.4	Low-Emitting Materials - Composite Wood and Agrifiber Products	1
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems - Lighting	1
		1	Credit 6.2	Controllability of Systems - Thermal Comfort	1
1			Credit 7.1	Thermal Comfort - Design	1
1			Credit 7.2	Thermal Comfort - Verification	1
		1	Credit 8.1	Daylight and Views - Daylight	1
1			Credit 8.2	Daylight and Views - Views	1
3	3	0	**Innovation and Design Process**	Possible Points	6
1			Credit 1.1	Innovation in Design : Specific Title	1
1			Credit 1.2	Innovation in Design : Specific Title	1
	1		Credit 1.3	Innovation in Design : Specific Title	1
	1		Credit 1.4	Innovation in Design : Specific Title	1
	1		Credit 1.5	Innovation in Design : Specific Title	1
1			Credit 2	LEED Accredited Professional	1
2	0	2	**Regional Priority Credits**	Possible Points	4
1			Credit 1.1	Regional Priority: Specific Credit	1
1			Credit 1.2	Regional Priority: Specific Credit	1
		1	Credit 1.3	Regional Priority: Specific Credit	1
		1	Credit 1.4	Regional Priority: Specific Credit	1
66	22	20	**Totals**	Possible Points	110

Certified: 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110 points

The U.S. Green Building Council’s LEED rating system is currently on its third major release, called “LEED 2009.” The checklist approach allows different team members to share information with a common set of assumptions and definitions. *Image courtesy of U.S. Green Building Council. Used with permission.*

efficiency and environmental performance. A number of different rating systems and guidelines have been developed for this purpose. The challenge in creating a rating system is that it needs to be simple enough that it can easily be applied to a variety of projects, but with sufficient complexity to reflect true differences in environmental performance. A number of different systems have been created in the last 20 years or so, all attempting to be easily integrated into practice to influence conventional decision-making patterns in practice. One of the earliest, in 1990, was BREEAM, developed in the United Kingdom, followed by LEED, developed in the United States. A few years later others were developed such as CASBEE in Japan, and Green Globes, which grew out of BREEAM implementation in Canada.

BREEAM

In 1990, a system was created in the United Kingdom called BREEAM, the Buildings Research Establishment Environmental Assessment Method, which breaks down building systems, components, and operations and ranks them based on the carbon impact of each decision. It includes assessment in nine different categories:

Management
Health and Well-being
Energy
Transport
Water
Materials and Waste
Land Use and Ecology
Pollution
Innovation

Each project receives a score for each category, is assigned a weighting according to the environmental impact of each category, and the resulting score will indicate achievement of one of five levels—Pass, Good, Very Good, Excellent, or Outstanding. Projects below a threshold will not pass. Over the last 20 years the system has been broadened to include specific systems for different types of buildings, such as offices, education, healthcare, and retail, and has other systems geared toward larger developments, core and shell development, and existing building assessment. Recognizing that some broad requirements should be applied differently to building types where conventional criteria may not be applicable, there is a process in place where specialized projects can be assessed using a customizable system, called "BREEAM Other Buildings" (formerly known as BREEAM Bespoke). This process involves working with the founding organization, the Buildings Research Establishment (BRE), to have a project-specific system developed. Although there is not a laboratory-specific system, BRE specifically notes labs as a good fit for the BREEAM Other Buildings process. One unique aspect of this system is the integration of the practices and materials of design of the building with the operation and management of the building.

BREEAM is a registered trademark owned by the BRE Group. *Image reproduced by permission of the BRE Group.*

LEED

Founded in 1993, the U.S. Green Building Council (USGBC) developed a rating system called "Leadership in Energy and Environmental Design (LEED),"

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a broad-based, consensus-driven process that included government, manufacturing, and design and construction professionals in the process, the main goal being to create a system that would transform the market. By having a system that started with modest yet important improvements over conventional practice, tying the requirements to standards that would get progressively more stringent, the system would change both conventional practice and the definition of green building. The system starts out with a set of prerequisites that all projects need to meet to start the assessment process, which sets a threshold of aspects that all "green" projects should achieve. Similar to BREEAM, there are categories of different strategies, and four different levels of certification—here the levels are called Certified, Silver, Gold, and Platinum. The first pilot rating system was introduced in 1998, and the formal issue of the program was in 2000. Over the next few years, additional systems were introduced to focus on Interior Fitout (Commercial Interiors), Core and Shell development, and a system focusing on existing building operation. An additional system has been developed for Schools, and systems are being developed for Retail, and Healthcare. Building on work developed by the Labs21 team (see below), there was a preliminary guideline for laboratories developed for LEED in 2005. This guideline is still in draft form, and it is unclear when the USGBC will finalize or issue it publicly. It is a useful document for reference, but not as helpful as the resources developed and revised by the Labs21 partnership.

Labs21

In the mid-1990s, a partnership between the U.S. Department of Energy, and the U.S. Environmental Protection Agency was formed to develop tools and resources for high-efficiency laboratory facilities. Called the "Laboratories for the 21st Century," or "Labs21" for short, this program brought together designers, engineers, and policymakers from different groups and developed resources very useful to lab owners, designers, and operators. The organization's first public conference was held in 1999, with attendance by federal agencies, public utility and service companies, along with research universities and private companies. (labs21 conferencehistory2009_508.pdf)[3]

Focusing on energy efficiency in design and operation, reduction in water consumption and emissions, protecting occupant safety, and using an integrated "whole building" approach to laboratory design, the Labs21 program offers several different types of resources that can help in lab design and operation. The core resource is the Labs21 Toolkit—a suite of tools that includes Best Practice Guides focused on laboratory-specific technologies, Case Studies of high-performance laboratories, a Design Guide, an Energy Benchmarking Tool, and several design support tools including the Labs21 Environmental Performance Criteria (EPC).

The Labs21 EPC is a rating system for use by laboratory building project stakeholders to assess the

Image courtesy of NREL, Laboratories for the 21st Century (Labs21®).