Energy Efficiency Programs for Niche Markets: The Labs21 Program as an Exemplar

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ABSTRACT

Most federal programs that promote energy efficiency and environmental sustainability in the building industry focus on the larger market segments such as offices, residential buildings, etc. Niche markets such as laboratories are often overlooked and beyond the scope of such programs, for at least two reasons: a) by definition, niche markets are a relatively small "wedge" of the overall energy consumption "pie"; and b) laboratories have health and safety concerns, complex flexibility requirements and are perceived to be less amenable to broadly applicable strategies.

Nevertheless, laboratories and other "high-tech" buildings demand the attention of the energy efficiency and sustainable design community for several reasons:

- They are a growing segment of the building sector.
- They are very energy and resource intensive – laboratories on average are four to six times as energy intensive as office buildings, and five to ten times as expensive to build.
- There are significant opportunities for efficiency and conservation, especially when compared to other buildings.

In this paper, we describe how the Labs21 program, a joint program of the US EPA and US DOE, is structured to meet these needs recognizing that laboratories require very specialized engineering and design knowledge not addressed in academia or industry, and not readily shared to a level commensurate with the needs of this building sector. While Labs21 is focused on one niche market, we also highlight some experiences from this program applicable to other specialized building types.

Introduction – What's So Special about Laboratories?

> "[a]s a building type, the laboratory demands our greatest attention: what the cathedral was to the 14th century, and the office building is to the 20th century, the laboratory is to the 21st century. That is, it is the building type that embodies, in both program and technology, the spirit and culture of our age and attracts some of the greatest intellectual and economic resources of our society."
>
> *Donald Prowler, FAIA*

To appreciate the challenges that laboratories present to designers and engineers, we must appreciate their purpose. The activities within educational laboratories are based on extensive and repetitive experiments that become a major guiding factor in the design of the laboratory.

These experiments place special requirements on the architectural features and engineered systems of the educational laboratory, establishing the expectations for its performance. However, other varied factors enter into the design of educational laboratories and introduce challenges, such as student maturity, pedagogical approach, technological evolution, student participation, and more. In accounting for these variables, the laboratory designers must ensure the laboratory provides a safe, effective and flexible learning environment.

The research laboratory on the other hand is replete with its own extraordinary requirements. Here, there is often far less information available for its design and engineering since repetitive science is not the objective of its users. The demands on a research facility will be more varied, unpredictable, and extreme, likely affecting the daily operations of the facility. Research activities will influence the laboratory's safety, utility services, and physical capacities. Furthermore, it isn't rare that the users will have the ability to influence the laboratory management due to their standing in a scientific community. And although a design team may incorporate users throughout the planning and design process, many assumptions prevail that create an expansive set of design requirements that overstate the facility's capacities.

This only begins to touch on the myriad of issues facing designers, engineers and constructors of laboratories. In creating a laboratory, or even upgrading an aging facility, the architect and engineer are faced with a complex set of requirements under which they develop their solutions for these extremely unique facilities. The very concept behind science is the desire to understand why a thing exists or how it operates. Attempting to explain scientific knowledge, Karl Popper [Popper 1968] poses a unique conundrum for architects and engineers when creating the laboratory through which scientific learning and advancement is expected to occur. The laboratory, by concept, must be capable of being at the unknown frontier of knowledge, but it must exist in the present moment, grounding its capacities to the reality of our human endeavors. The challenge for laboratory designers is to embrace this dichotomy of purpose, while providing a safe and healthy workplace, and furthermore, with due consideration to resource conservation and protection of the environment.

But why concern ourselves with having laboratories that are environmentally sound, energy efficient and conserving of natural resources? Unfortunately, laboratories have historically been designed with little attention to the use of resources and impact on the environment. As a result, laboratories typically utilize four to six times as much energy as a conventional office building on a square foot basis, often many more times the use of water, and in some cases these multiples can be even more excessive (energy use intensity in certain physical laboratories can be over 10 times the average office building). This level of consumption creates demands against existing supplies that affect neighborhoods, towns, and even cities. It also creates unwanted emissions associated with electricity production and increases chemical use for potable and wastewater treatment.

The question posed by the U.S. Environmental Protection Agency and the U.S. Department of Energy, through their co-sponsorship of the Laboratories for the 21st Century (Labs21) program, is how we should ensure that laboratories, many of which are concerned with the study of the natural world, do not negatively impact that which they are intended to study.[1]

[1] Consider the fact that fume hoods, a standard safety device employed in chemical laboratories, each use as much energy as three standard homes. Thus, as scientists demand more and more hoods per researcher, the corresponding energy impact is equivalent to a small neighborhood. The use of potable water for laboratory bench-top equipment cooling also adds significantly to the overall environmental impact of a laboratory.

Labs21 maintains that most existing laboratories can reduce their energy consumption and associated air pollution by 30 percent with the application of advanced technologies such as high performance fumehoods. This rate can be exceeded by using a comprehensive systems integration strategy that incorporates combined heat and power technologies. Labs21 estimates that financial savings attributed to a 30 percent reduction in energy use from the laboratory sector of the building market could be over $1 billion annually. Other considerations include water recovery, increase use of sustainable building materials, material reuse and recycling, risk management, hazard management, and space flexibility. Together with the savings generated by energy efficiency and resource conservation, substantial cost reductions may be realized.

An additional cost factor, not as well defined but having a potentially greater significance, is the quality of workspace space that may play a large role in employee retention (or student attraction), satisfaction and productivity. A growing body of information is attempting to quantify the potential significance of better-designed and functional workspaces [Loftness and Hartkopf 2002].

In summary, architectural design and systems engineering must demonstrate the values of and reasons for the science conducted within the laboratory. The laboratory may be one of the few building types to support the use of true building life cycle cost decision-making because the building is not speculative, it has an expected long life, and the greatest assets are the scientists and technicians operating within it. Furthermore, because of the significance of the scientific and safety activities occurring daily within laboratories, they tend to need a more competent facility management staff. Taken together, these considerations support the Labs21 mission i.e. encouraging laboratory owners to pursue increased environmental performance, energy efficiency and resource conservation in the design and engineering of laboratories in the 21st century.

The Case for a Labs Program

Experience from EPA's Own Laboratories

In 1992, with the passage of the Energy Policy Act and working to meet the reporting requirements for federal agencies, EPA learned that it was the highest consumer of energy per square foot for all reporting federal agencies. This fact was only mollified by DOE, with its extensive laboratory and industrial complexes, being a close second.

EPA investigated this situation and made a number of findings. First, many agencies were either not reporting their laboratory or industrial energy use as provided for by an exemption clause in the act (which EPA chose not to exercise) or had substantial non-laboratory space that diminished the overall impact of the labs on their total level of consumption. Second, EPA was reporting only laboratory energy consumption; all EPA office space was managed, therefore reported, by the General Services Administration. Third, after reviewing the agency's laboratory energy consumption, lighting upgrades that were the original focus of energy efficiency for EPA and were expected to produce a noticeable reduction in the electric power usage, were determined to provide much less than 10 percent of a laboratory's total energy use.

The energy management team for the agency needed to find a solution that it could afford and that provided a comprehensive and effective solution to laboratory energy use. By studying the HVAC systems in the EPA laboratories, and when considering the new technologies coming to market in the 90's, a strategy was conceived that relied on integrating energy recovery, free or renewable energy, a higher level of building monitoring and control, new cooling and heating systems, and combined heat and power technology.

The challenge was not small. The agency had to find a pilot test site that had a management team and users who were willing to pursue a retrofit based on a comprehensive, though unproven, energy efficient solution. And, if one could be found, identifying an engineering firm willing to undertake the project. In addition, senior EPA management needed to be convinced that the project was worth the investment, expected to be in the millions of dollars.

In 1997 the financial investment was the first part of the puzzle to be solved. That year the Federal Acquisition Regulations were modified allowing federal facilities to utilize third party investments in energy using building equipment. The Department of Energy's Federal Energy Management Program was responsible for these modifications as allowed under the Energy Policy Act of 1992. Energy Savings Performance Contracting, as it became known, was the financial avenue necessary to address the comprehensive solutions envisioned by EPA and was integral to proving such solutions were an effective approach to improving energy performance in laboratories.

What still remained were two crucial issues identified earlier: a) identifying an EPA facility that would permit a project of this nature to be implemented, and b) identifying a firm that would be willing to engineer, purchase, install and guarantee savings under such a contract vehicle.

A Case in Point – EPA's Ann Arbor Laboratory

The National Fuel and Vehicle Emissions Laboratory in Ann Arbor, Michigan, happened to be one of the higher users of energy per square foot in the agency's inventory, and was willing to serve as a test site for these concepts.

After a lengthy and exhaustive study that produced a set of engineered HVAC solutions, EPA's energy team presented the laboratory management and staff with its proposal. In the information shared with the lab, the team included the fact that the building needed many of its energy using systems, in fact its whole infrastructure, replaced and that the chance of that occurring, and occurring at one time of (in)convenience, was next to zero given the cost of such a project. Information was also shared that showed that financing a project was possible, that the resulting system would be a clear demonstration of technology and efficiency (though in a building) that they themselves knew were the solutions for automobile efficiencies. Furthermore, the laboratory would benefit from greater control and management of its mission, and contribute far less to the degradation of the regional environment based on the source of its electric power.

In the spring of 1997 EPA issued its request for proposals based on the comprehensive solution its energy team envisioned and awarded a contract in the fall to NORESCO, the winning firm. By 2000, NORESCO's comprehensive project was completed having a cost of nearly \$11 million with a simple payback of fewer than 10 years. To date the project has exceeded its energy use reductions and continues to support a very unique laboratory operation. This initiated the Laboratories for the 21st Century program within EPA.

The Ann Arbor project had a variety of significant energy conservation measures included in the upgrade (Table 1). Each of these items contributes toward or directly generates energy efficiencies that produce the energy and water savings noted in figures 1-3.

Table 1. List of Efficiency Measures Installed in the Ann Arbor EPA Laboratory

1) Replacing 14 rooftop air handlers serving the automotive testing cell with indirect evaporative coolers, preheat coils with face and bypass dampers, and spray atomizing humidifiers.
2) Replacing 4 roof mounted HVAC units with water cooling and heating and integrated energy recovery wheels and heatpipe system to service the automotive testing preparation bays.
3) Replacing 11 new rooftop air handlers for laboratory office spaces.
4) Replacing 35-year-old boilers and chillers with double-effect, dual fuel, absorption machines producing hot and chilled water, and replacing water-cooling tower.
5) Replacing pneumatic controls with advanced direct digital control energy management system with extensive monitoring and control capabilities.
6) Installing water circulating cooling system for laboratory equipment.
7) Installing capacitors and controls to increase the facilities power factor to a minimum of 90 percent.
8) Installing a 200 kw natural gas fuel cell.
9) Expanding the services of the central cooling system to the laboratory's cold test bay replacing the existing reciprocating chillers.

Figure 1. Electricity Utility Costs Profile for EPA Ann Arbor Laboratory (1999-2002)

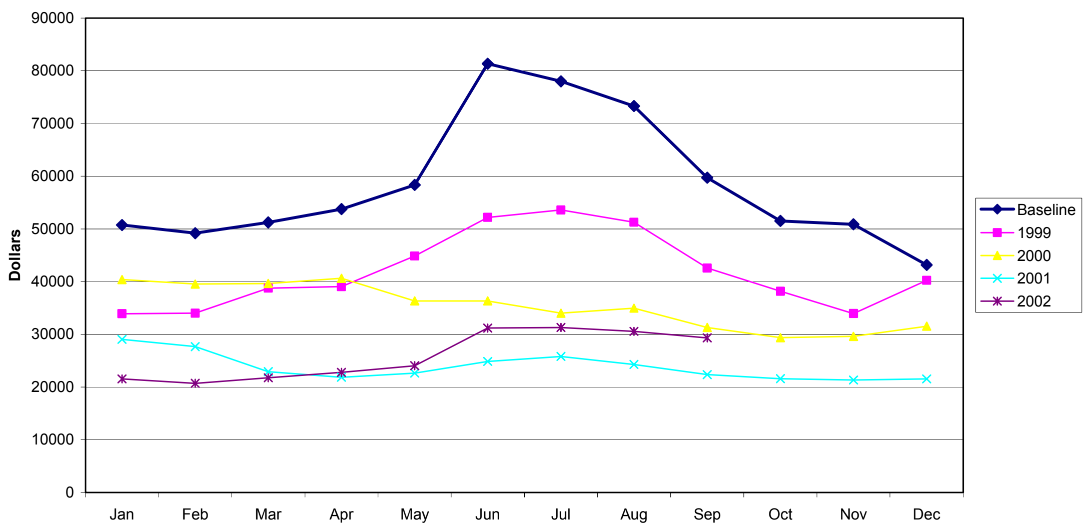


Figure 2. Peak Demand Profile for EPA Ann Arbor Laboratory (1999-2002)

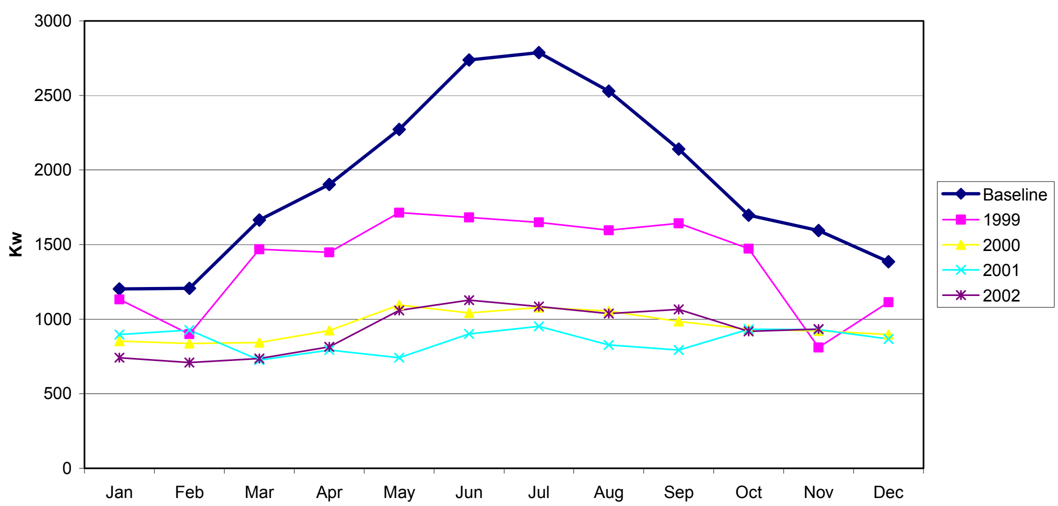
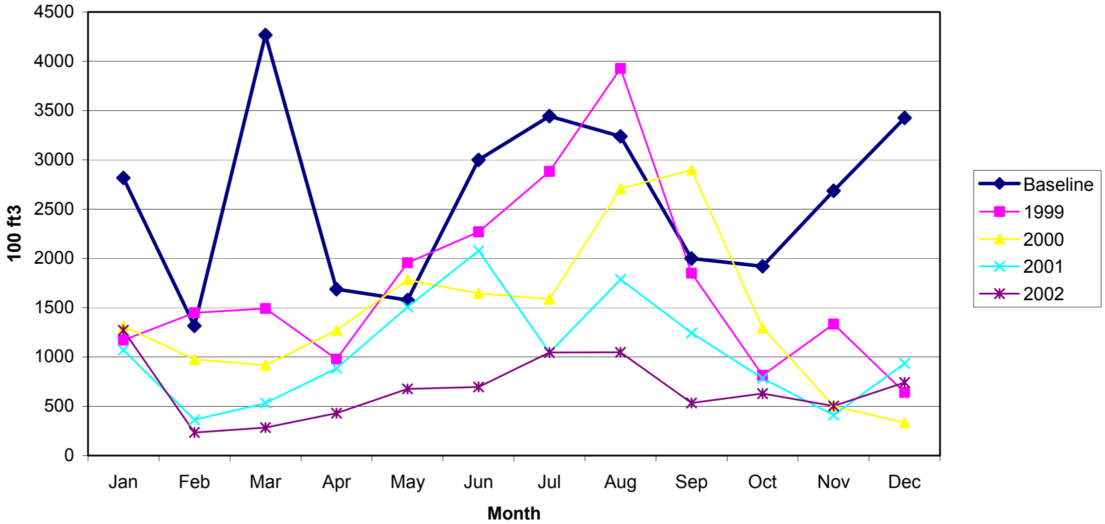


Figure 3 Water Use Profile for EPA Ann Arbor Laboratory (1999-2002)



The value of undertaking this project at EPA is without measure. The risks, the challenges and persistence which produced this successful project demonstrated then and continues to demonstrate today that laboratories have significant opportunities for energy efficiency, and that the strategy utilized in that project is replicable in achieving significant reductions in energy use. The laboratory may be one of a few building types where these techniques and technologies are life-cycle cost effective and where the facilities management staff is best suited to tackle the challenges these solutions present.

EPA discovered that when designing or improving a laboratory, a significant number of stakeholders needed to be recognized and their needs addressed as they affected both design and final facility operation. Some of the more obvious, but not least of these, included environmental health and safety staff, users, operators, managers, owners, constructors, designers and engineers, each having their own special needs, whether it be risk, access, flexibility, storage, etc.

Existing programs such as ENERGY STAR and the Federal Energy Management Program were developing tools and engineering strategies under executive orders and legislation that were geared to major sectors of the building industry and included commercial offices, schools, and single and multi-tenant housing. DOE's Office of Industrial Technologies was addressing energy efficiency solutions for manufacturing and processing. Laboratories had no federal advocacy even though many federal agencies owned or operated R&D centers, laboratory facilities, or were in some way responsible for laboratory construction, e.g., federal grants.

EPA's experience began to raise the significance of the capital investments being made by U.S. laboratory owners, the significance of the operational costs associated with ownership, and the significance of the work carried-out in these facilities. Noting the complex needs of the stakeholders and the future value of these facilities to the U.S. economy, EPA created the Labs21 program as a forum for with the broader mission to improve the environmental performance of the nation's laboratories. In doing so, laboratory facilities will help to usher in to the marketplace the sustainable and energy efficient strategies being demanded more and more of the U.S. building industry.

Labs21 Program Structure and Components

Overview

Labs21 is a voluntary partnership program jointly sponsored by the U.S. Environmental Protection Agency's Office of Administration and Resources Management and the U.S. Department of Energy's Federal Energy Management Program. Conceived on the experience of the Ann Arbor laboratory, the partnership program works to improve the overall environmental performance of U.S. laboratories. The program encourages through design, construction, and operation the creation of new or retrofitted laboratories that will:

- Minimize overall environmental impact
- Protect occupant safety
- Optimize whole building efficiencies on a life-cycle basis

The CBECS [EIA 1999] database indicates that laboratories are about 0.1% of total commercial buildings floor space in the United States, and account for about 2% of total energy expenditures in commercial buildings. (Note that CBECS classifies lab buildings as those that have more than 75% lab space. However, most laboratory buildings have less than 75% net lab space, and so laboratories would actually constitute a larger portion of commercial building energy use and floor area than the CBECS data would indicate.) The eight published Labs21 case studies show that savings potential varies from 30-60%. On a national level, this would translate into between $500 million to $1 billion in annual energy savings, which in turn would account for about 20 percent of the $5 billion annual savings potential in the commercial building industry. Thus, while laboratories are indeed a niche in the commercial building sector in terms of total energy expenditures, they have a disproportionately high share of the energy savings potential.

Labs21 currently has three components: 1) Partner program, 2) Training, and 3) Toolkit. Each of these is described in more detail below.

Partner Program

Labs21 has established voluntary partnerships with interested public and private sector laboratories. The goal of this component is to encourage these laboratories to adopt sustainable practices and to disseminate the lessons learned to the wider laboratory community. Working with the Labs21 program, each partner is setting voluntary energy and water efficiency goals, applying sustainable design and engineering practices, and measuring and reporting the success of their efforts. For its part, Labs21 offers the partners technical assistance, and official recognition. Table 2 indicates current private and Public sector partners.

There is also a supporter program for organizations such as architectural firms, which do not own or operate laboratories, but that have a keen interest in promoting sustainable design in laboratories.

Table 2. Current Labs21 Partners

Private Sector	Public Sector
• Bristol-Myers Squibb • Carnegie Mellon University • Duke University • Harvard University • New York City School Construction Authority • Northern Arizona University • Raytheon • Sonoma State University • University of California-Merced • University of Hawaii • University of North Carolina-Asheville • Wyeth	• Lawrence Berkeley National Laboratory • National Oceanic Atmospheric Administration • National Renewable Energy Laboratory • Sandia National Laboratories • U.S Department of Agriculture • U.S. Environmental Protection Agency

Training

Labs21 provides a range of training and educational opportunities on sustainable laboratory design and operation. Courses, competitions, and networking forums allow members of the laboratory community to exchange information and share best practices on the environmental performance of laboratories.

Design Course: Labs21 currently offers a one-day course that introduces strategies for designing and constructing sustainable laboratories in both new and existing facilities. The course includes sessions on the architecture and engineering of high-performance laboratories, as well as benchmarking and case studies. Labs21 typically works with other organizations such as ASHRAE, USGBC, AEE and many others willing to sponsor a course. The course is typically offered 8-10 times throughout the year, and to date about 1200 professionals have been trained.

Labs21 is also in the process of developing a series of advanced course modules that can be combined in various ways to create customized courses suited to different audiences.

Annual Conference: This has become a highly attended gathering for international laboratory designers and engineers. The 3-day conference provides a forum for information exchange through papers, poster sessions, and roundtables. The conference also includes several tours of laboratory facilities with unique systems or aspects of design or engineering. The conference is arguably the most successful component of the program, drawing over 500 attendees at the last conference. Entities from Canada, Australia and New Zealand are contemplating replicating the program in their respective countries.

Roundtables: These working groups comprised of professionals are facilitated by Labs21 to draw attention to the issues of the variety of laboratory types in existence or planned. From particle and plasma physics to marine biology and nanotechnology, laboratory work presents new demands, hazards, and sensitivities that are not often repetitive and require an ever increasing and well maintained knowledge base. Through these working groups, Labs21 draws a focus on the issues presented by the science and hopes to evoke solutions from the experts participating in the groups. Labs21 currently has working groups dealing with the learning laboratory, bio-containment, cleanrooms, laboratory equipment, pharmaceuticals, marine, laboratory codes and standards. In addition, Labs21 continually encourages the development of new working groups.

Student Design Competition: Labs21 has partnered with the Association of Collegiate Schools of Architecture (ACSA) to develop a student design competition for sustainable laboratory design. The Public Works and Government Services Canada are also partners in this endeavor. The competition was announced in the spring of 2003 and will be awarded at the 2004 Labs21 conference. The competition challenges architecture students and faculty from the United States and Canada to design a laboratory building that exemplifies high performance, low-energy design principles, in addition to meeting core architectural design considerations. Over 500 students have registered for the competition.

Toolkit

Labs21 offers an integrated tool kit of resources to support the design, construction, and operation of high-performance laboratories. Table 3 lists each of the tools and their primary purpose. A comprehensive description of each of these tools is beyond the scope of this paper, and a more detailed documentation is available in other publications [Mathew et al. 2002, 2003]. All the tools are publicly accessible at http://www.labs21century.gov/toolkit/index.htm.

Table 3. The Labs21 Toolkit

Tool	Purpose
Design process tools:	
Labs21 Process Manual	Guidance for sustainable design process.
Design Intent Tool	Documentation of design intent – objectives, strategies, metrics.
Environmental Performance Criteria	Point-based rating system for sustainability, based on LEED™.
Core information resources:	
Design Guide	Reference manual on energy efficiency features in laboratories.
Best Practice Guides	Information on design, construction and operation of specific technologies and strategies.
Case Studies	Whole building case studies of high-performance laboratories.
Energy Benchmarking	Energy use data for laboratory systems and buildings.
Overview resources:	
Intro to Low-Energy Design	Overview of key strategies for high performance labs.
Labs21 Video	Examples of high performance labs.

The toolkit provides an effective means to support a sustainable design process in laboratories, because of these key features:

- Scope: The toolkit has rich knowledge base in both breadth (range of topics covered) and depth (level of detail for each topic).
- Process support: The toolkit includes tools that are explicitly designed to support the design process and documentation of owner objectives for the laboratory.
- Context-specific linkages: The tools are interlinked, but not inter-independent. This provides flexibility in how the tools are used (i.e. it does not prescribe a particular path in the design process) while at the same time enhancing their effectiveness by providing content-specific links to other tools.

Outlook and New Initiatives

Over 5 years since its introduction as a national program, the Laboratories for the 21st Century (Labs21) program has seen remarkable success and growth, as an un-mandated federal initiative. The continued value of the program to this market sector can be expected to continue due to the on-going shift within the U.S. from manufacturing/production to services and R&D. Production and manufacturing components of existing U.S. businesses including pharmaceuticals, chemicals, electronics and others have shifted to countries with lower wage demands such as Mexico, China, and India. A growing investment throughout these businesses is in the upgrading or building of new research and development capabilities, especially within the U.S.

Additionally, the U.S. continues to place great emphasis on the education of future generations. Considering the shift in business activity emphasizing the development of new products, cures, and services, the competition for leadership in these areas will demand high quality employees and laboratories that meet ever growing functional expectations.

The newest and now rapidly growing sectors of research including nanotechnology, bioengineering and robotics, microelectronics, and infectious diseases are already causing the creation of facilities not only at corporate and government sites but university campuses. So great is this demand, that more and more colleges and universities are engaged in capital expansion programs based on the attraction and retention of staff and students. For example, the University of California (a Labs21 partner) is projected to build 17 million sq. ft. of lab space over the next few years. Another partner, Duke Medical Center, will build 5 million in that same time-frame.

However, within this expansion is the recognition that these facilities must achieve their functionality through a growing commitment for exceptional environmental and energy performance. To date, many schools of architecture and engineering have focused their efforts on non-laboratory buildings and until most recently the goals for sustainability and energy efficiency in laboratories have not been addressed. This has left the current field of architectural and engineering professionals engaged in designing and building high performance laboratories with the scattered knowledge gained from their practice.

Labs21 is addressing this situation by 1) gathering under one banner the current knowledge on design and engineering of high performance laboratories, 2) providing a neutral forum in which practicing professionals can readily share their knowledge and experiences, 3) using this forum as a means of forecasting industry trends and preparing professionals to meet the new demands, and 4) ensuring that the knowledge and experience of these professionals are captured and made available to students of architecture and engineering.

Centers of Excellence

Labs21 also is increasing its value by encouraging the development of “Centers of Excellence” that will work with specific sectors of laboratory community to better understand the issues of diverse laboratory types, identify and test solutions, and implement solutions in actual projects.

This is happening on several fronts. The long-standing learning laboratory working group has spun-off a “Center of Excellence,” recognized as such by Labs21 (EPA and DOE), at the Virginia Polytechnic and State University (Virginia Tech). The Virginia Tech Labs21 center, called the Center for High Performance Learning Environments, is working with inner city school systems such as the New York City School Construction Authority and rural schools including the Franklin County Virginia Schools, beginning to conduct research and assist schools in developing sustainable learning laboratory where the building participates in the education and pedagogy of instruction.

The University of Hawaii's School of Architecture is recognized as a Labs21 Center of Excellence in researching the design and engineering of sustainable marine laboratories and aquaria. The school will not only be conducting research but developing a curriculum on the design and engineering these labs. It is also working with the Hawaii School of Marine Sciences in building a new laboratory under their Labs21 partnership.

Labs21 is supporting other activities that could become centers of excellence. Harvard's School of Public Health is working on laboratory codes and standards and the University of California is working on energy efficient laboratory equipment. Other opportunities for establishing new research and assistance centers will likely occur as new areas of research and learning are required and the demand on the design and engineering community increases.

Conclusion

EPA and DOE appreciate the complexities and challenges laboratories present to designers, engineers, owners and users. Having the responsibilities to manage their own laboratories, these agencies have recognized that those working in the laboratory design and engineering industry have developed this same appreciation and are the greatest resources these agencies will have in promoting sustainable, high performance laboratories, capable of supporting the ever-changing nature of research, testing, and learning. It is with this recognition that EPA and DOE turn to the industry to better understand laboratory needs and provide for the exchange of information among those who are best qualified to deliver solutions.

EPA and DOE will likely continue to promote energy efficiency under the various programmatic federal program addressing commercial, residential, and manufacturing facilities. ENERGY STAR, Climate Wise, Energy Smart Schools, and a myriad of well-run and successful programs will help shape energy efficiency and energy systems into the future.

EPA, along with DOE, continues to support the program and the interest it has developed has allowed Labs21 to continue to expand its reach. At this writing, Labs21 has 1) over 2600 (and growing daily) lab designers and engineers receiving monthly communications about the program, 2) a growing level of interest in partnering with EPA/DOE from universities, industry and other federal agencies, 3) commitments from Canada, Australia and New Zealand for replicating and internationalizing the program, 4) over 500 attendees at the annual international conference, 5) and over 1200 designers and engineers trained by Labs21.

EPA, with DOE support, has provided extraordinary leadership in this effort. This unique and highly successful collaboration has brought significant benefits back to the federal government. In part, this is evidenced by these agencies' reputation throughout the federal community for tackling the difficult and long-ignored problem of excessive energy consumption in laboratories. But it also is evident in the growing numbers of agency Labs21 partnerships.

Labs21 has been highly creative in leveraging industry and academia to move the laboratory marketplace to higher levels of environmental performance in the building industry. Many of the Labs21 tools have benefited from hundreds of volunteer person-hours. Although laboratories may be considered a niche market within the building industry, the interest in laboratory design that it produces is a ground swell, which will emanate well beyond the bounds of this limited market.

Laboratories will continue to house the work of various energy efficiency programs, will be the cradle of all manufacturing activities, will educate future scientists, will continue to be one of the best opportunities to support sustainable building practices, and will always be at the forefront of creating better and more livable world. Whether they are in an out-of-the-way location at a small rural high school, or at a major pharmaceutical company, or in the Antarctic, our future depends on their viability, their design for purpose, their safety, and, dare we say, vision.

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