

# LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES

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## THE LOUIS STOKES LABORATORIES, BUILDING 50, NATIONAL INSTITUTES OF HEALTH, BETHESDA, MARYLAND

### Introduction

The Louis Stokes Laboratories, Building 50 at the National Institutes of Health (NIH) in Bethesda, Maryland, reflects a strong commitment to the energy-efficiency goals of the Laboratories for the 21st Century program, a joint endeavor of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). In an aggressive approach to energy efficiency, the building incorporates the use of daylighting, variable-air-volume (VAV) control of the ventilation air supply and exhaust, and energy recovery from the exhaust air stream. Using a modified interstitial space as a core design feature, the NIH building is flexible enough to accommodate change and ensure that it will be used both now and in the future. The study is geared toward architects and engineers who are familiar with laboratory buildings. This program is part of a series that encourages the design, construction and operation of safe, sustainable, high-performance laboratories.



United States  
Environmental Protection  
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Department  
of Energy





The laboratories were ready for their first occupants in April 2001. The design team has received numerous awards for the energy-efficient design, which allows the building to use significantly less energy than a conventional laboratory building. This case study highlights the features that make the most significant contributions to these energy savings and include the use of daylighting, VAV systems for the supply and exhaust air, VAV fume hoods, variable-frequency-drive (VFD) motors, and desiccant energy-recovery “heat wheels” in the building’s supply and general exhaust system.



*“Scientists appreciate the new vision used in the design of the new labs. The large, open working areas will lead to more communication and interaction. Researchers will greatly appreciate the daylight and space.” Dr. Maria Morasso, scientist, speaking at the dedication of the Louis Stokes Laboratories*



## Project Description

The facility is six stories tall and contains 294,532 gross square feet (ft<sup>2</sup>) (27,363 m<sup>2</sup>) with 186,062 net ft<sup>2</sup> (17,286 m<sup>2</sup>) of research laboratory space. The construction costs totalled \$76.8 million, or \$260 per gross ft<sup>2</sup>. Hansen Lind Meyer (HLM) Architects of Bethesda, with Ross, Murphy, Finklestein (RMF) Mechanical Engineers of Baltimore and GPR Lab Planners of Purchase, New York, designed the building. The government’s construction quality manager was Jacobs Facilities of Arlington, Virginia, and the general contractor was the Bell Company of Kensington, Maryland.

Construction was completed in Summer 2001. Phase 1 of the construction—which involved clearing the site, relocating utilities, and providing more than 200 caisson foundations (drilled piers)—began in July 1997 and took 7 months to complete. Phase 2, which included completion of the building frame and enclosure and the electrical, mechanical, vertical circulation, and telecommunications systems as well as the fit-out and finishes, began in April 1998. Occupancy began in April 2001, and the facility should be fully occupied in October 2001.

The building will be used for structural and cell biology research, replacing three outdated facilities. It will provide space for 650 scientists from nine NIH institutes performing structural and cell biology research in these areas: allergy and infectious diseases; heart, blood, and lungs; diabetes, digestive system, and kidneys; the human genome; arthritis and the muscular-skeletal system; eyes, dental, and hearing; and skin diseases.

Building 50 houses six floors of lab space plus a basement vivarium and a mechanical penthouse. There is an interstitial mechanical level above each occupied floor. The labs are primarily rated as Biosafety Level 2 (BL2), meaning they are suitable for work involving agents of moderate potential hazard to personnel and the environment.

There are several specialized areas in Building 50, including an animal vivarium with Biosafety Level 3 (BL3) and quarantine isolation suites, a nuclear magnetic resonator (NMR) laboratory, a cryogenic electron microscope (EM) suite, and a BL3 infectious diseases laboratory. Air-transmissible diseases are studied in the BL3 suites; therefore, extreme care is required in the design of supply and exhaust air systems. The building’s space is broken down in Table 1.

The basement contains the mechanical and electrical support spaces and a 30,000 gross ft<sup>2</sup> (2,787 m<sup>2</sup>) vivarium with four levels of disease barriers. It has 14 animal holding rooms of various sizes arranged in four major suites with procedure rooms. The 3000 ft<sup>2</sup> (279 m<sup>2</sup>) specialized high-performance EM suite will contain six electron microscopes and a unique NMR facility that will house several large NMRs, including two of the strongest in the world. A 900 MHz machine is planned to be hoisted in place through a removable roof hatch using a special

**Table 1. NIH Louis Stokes Laboratories Space Breakdown**

(Net ft<sup>2</sup>, unless otherwise noted)

Laboratory/office/support areas	133,896 <sup>(1)</sup>
Vivarium	16,235
NMR Laboratory	4,109
BSL 3 Suite	1,263
Other laboratory space	12,011
First-floor conference suite, break rooms, other conference rooms, main lobby	23,558
<b>Total net ft<sup>2</sup></b>	<b>186,062</b>
Other <sup>(2)</sup>	108,470
<b>Total gross ft<sup>2</sup></b>	<b>294,532</b>

1. The breakdown is in net square feet. Net square feet equals gross square feet minus “other.”

2. “Other” includes circulation, toilets, stair towers, elevator shafts, mechanical and electrical rooms and shafts, and structural elements like columns. For this building, the ratio of net to gross square feet is 63%. Interstitial space is not included.

rolling-beam crane built into the ceiling; these will enable scientists to move and replace magnets with relative ease. Building 50 also has a taller-than-usual mechanical penthouse because of the greater air handler height needed to accommodate the energy recovery wheels.

### Laboratory Modules

The laboratory modules were designed using an “open plan” concept. Each floor contains approximately 36,000 ft<sup>2</sup> (3,345 m<sup>2</sup>). There are two exterior balconies on each floor. The lab space on each floor is organized into six “neighborhoods” of lab modules grouped around a central core. These neighborhoods preserve the feeling of the older, smaller buildings that the scientists previously occupied. Each neighborhood contains seven or eight open lab modules.

Each lab module has an equipment room on its inner face, adjacent to the open lab peninsula bench (which is about 16 ft long). The lab bench casework is 40% rolling cabinets to allow the user to adjust the bench layout. At the end of the peninsula lab bench is an aisle separating the bench from the personal workstations, which are located along the windowed exterior wall. All the personal workspaces thus have direct natural lighting.

The windowed walls are about 18 ft (5.4 m) high, which permits a large amount of daylighting in the workstations and in the lab bench area. In each module, there are corner-enclosed offices at both ends of the windowed wall. Above approximately 8 ft (2.4 m), the office enclosures are made of glass so they do not block daylighting to the lab area.

The layout was designed to respond to users’ requests for adequate workstations with windows, computer space, and daylighting in the labs. All workstations and labs are equipped with jacks for telephones and the local area networks (LANs). Entrances to each neighborhood are equipped with proximity card readers to control access. Each of the 35 neighborhoods has a minimum of one fume hood. There are only 52 fume hoods in the entire building, a relatively low number in comparison to other NIH facilities, which average one fume hood for every two lab modules. The Louis Stokes Laboratories have 246 lab modules in all.

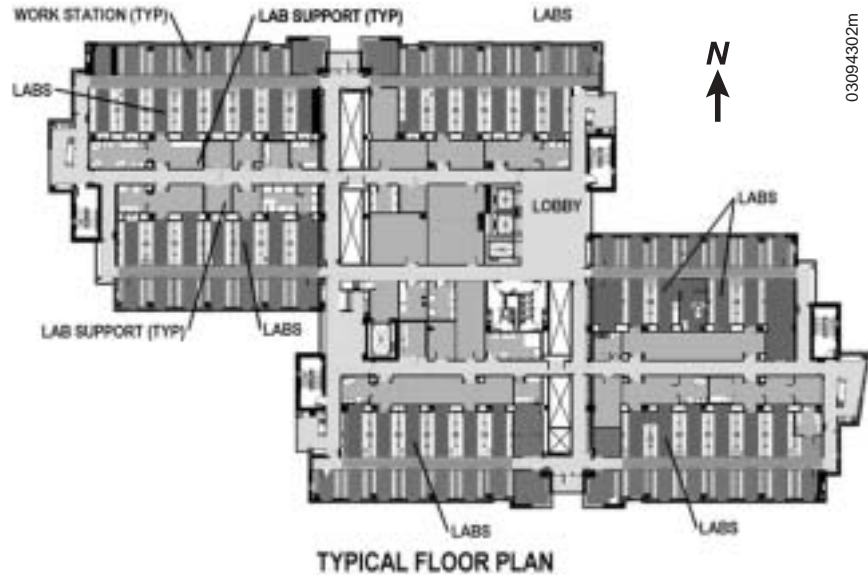


Figure 1. A typical floor plan for NIH Louis Stokes Laboratories. (Courtesy of HLM Design, Inc.)

### Utility Servicing

The heart of the building design is a modified interstitial mechanical floor located over each occupied floor. It is essentially a walk-on ceiling above the labs. All utilities are located in this interstitial area so maintenance workers can access the utility systems without entering the labs. This also helped to make the construction process more effective, as the workers could stand on the deck with their tools, plans, and materials instead of having to climb ladders or use lifts. The interstitial space is simply a suspended light steel deck with a clear height of 7 ft (2.1 m). It contains most of the heating, ventilating, and air-conditioning (HVAC), electrical, and plumbing equipment as well as telephone, LAN, and alarm system ladder trays. The supply and exhaust ductwork runs lengthwise along each side of a central corridor. The interstitial deck stops at the end of the lab benches, over the aisle between the lab bench and the personal workstations adjacent to the windows. This provides an opportunity for a higher ceiling over the aisle and the workstations. The resulting high, curved ceiling allows double-height windows to admit more daylight into the labs.

The major utilities, which are supplied from an adjacent campus central utility tunnel, are the chilled water supply and return, high-pressure steam and condensate return, and city water and compressed air. A basement mechanical room serves as the utility point of entrance and contains pumps and chilled water, steam, heat exchanger, and fire protection equipment. The main electrical transformer room, containing switchgear, and the



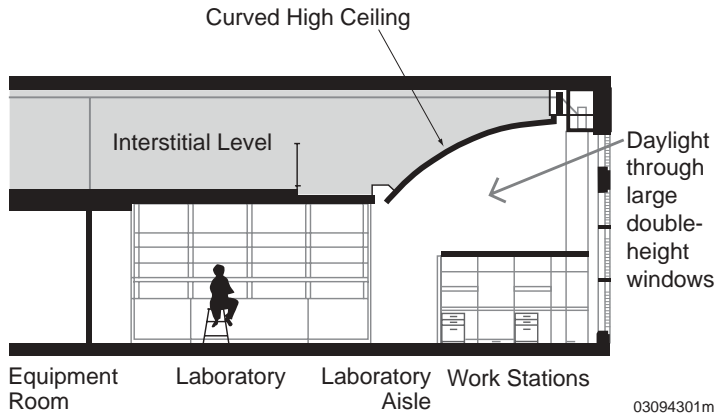


Figure 2. Cross section of laboratories and work stations shows daylighting through double-height windows. (Courtesy of HLM Design, Inc.)

emergency transformer room, containing switchgear and emergency transfer switches, is adjacent to the mechanical room. The emergency generator is in an at-grade enclosure next to the loading dock.

The piping distribution originates in the basement mechanical room and extends upward through the building in four major shafts. A second mechanical penthouse on top of the building contains the main air handling units, with the desiccant energy recovery wheels, exhaust fans, elevator machine rooms, and other systems.

Piped utilities for the labs include vacuum, air, natural gas, carbon dioxide, lab industrial water, lab waste, secondary chilled water, reverse osmosis water, and nitrogen gas. An internal building clean steam system services the autoclaves and humidifies the building. Liquid nitrogen is provided to limited specific locations in the NMR, freezer room, and EM suites in the basement. An exterior tank farm is adjacent to the loading dock.



*“The design of the Louis Stokes Laboratories, Building 50 at NIH, incorporated all feasible and practical high-performance, energy-saving features. Energy efficiency was one of the stated design goals.” Frank Kutlak, R.A., NIH Architect/Building 50 Project Officer*



## Design Approach

The architectural/engineering team was selected on the basis of prior experience in designing similar scientific research facilities in the mid-Atlantic area. The energy effectiveness of their designs was one of the criteria. The HLM architects and RMF engineers had completed two prior projects in the region, both of which employed desiccant energy recovery wheels.

In the planning documents, goals were established to do everything that was practical and feasible to conserve and recover energy in the design of the Louis Stokes Laboratories. Energy efficiency was a specific design goal in the conceptual phase of design. Energy performance modeling was done during the schematic design phase, and an energy study was conducted in November 1997 that culminated in a \$2 million rebate to the government from Potomac Electric Power Company (Pepco), the local energy provider.

The construction contractors were selected for the project using a unique method known as a “best value” procurement. In this method, a committee scored and reviewed the qualifications of the contractors and, in conjunction with their bids, selected the contractor that they felt represented the best combination of price and technical qualifications, and thus the best value to the government. Consequently, the lowest bidder was not the one selected in either of the two phases of construction.

## Technologies Used

The single largest energy consumer in the laboratories is the equipment that supplies and moves the large amount of ventilation air required to maintain a safe environment. Thus, HVAC design concerns focus on this requirement. The key technologies, covered in detail below, that are used to meet this requirement in an energy-efficient manner include these:

- VAV supply and exhaust systems
- VAV fume hood systems
- VFDs for fans and motors
- Controls and automation systems
- Desiccant heat wheels for energy recovery.

From an architectural standpoint, the key sustainable design feature in the building is the innovative method of capturing daylighting by ending the modified interstitial floors approximately 12 ft (3.7 m) back from the window walls and using a curved ceiling to take advantage of the full floor-to-floor wall height of 18 ft (5.5 m) and the double-height windows. The resulting daylighting is sufficient to light the office space as well as the lab bench areas, which are approximately 30 ft (9.1 m) in from the window walls. Lighting over the lab bench space consists of T-8 fluorescent lamps and electronic ballasts on photo sensor controls.



**VAV Supply and Exhaust Systems with VFD Fans**

For the building’s supply and exhaust system and fume hoods, NIH considered both constant-volume (CV) and VAV systems, and ultimately selected VAV with VFDs on the fan system. Rather than maintaining a constant air volume in the supply air, the VFDs on the Building 50 fan systems reduce the volume of air delivered to the space when the building is unoccupied, from a maximum volume of 400,000 cubic feet per minute (cfm), or 15 air changes per hour, to 160,000 cfm, or 6 air changes per hour. The variable-speed drives lower the speed of the supply and exhaust fans to accomplish this reduction and move less air. The VFDs do this 25% more efficiently than the standard inlet vane controls of the past. Although a VAV system has a much more complicated and expensive control system than a CV system, the VAV system uses 30% to 50% less energy than a CV system does.

The following factors were considered in evaluating CV and VAV systems. The NIH design guidelines required once-through air, allowed VAV, and specified a turn-down ratio of a minimum of 6 to a maximum of 15 air changes per hour. The load profile of the users indicated that there would be varying loads in the building. There is a moderate to high degree of variation in the climate (including temperature and humidity) throughout the year. A life-cycle cost study concluded that the payback period for the VAV system was shorter than that of the CV system, even though energy costs in the mid-Atlantic region are moderate. In addition, NIH maintenance staff have the capability to maintain highly flexible VAV systems.

This is the first NIH building to install VAV fume hoods; all the other fume hoods on campus are CV bypass hoods. VAV hoods are more expensive and complex to design, install, and commission, but they have the highest degree of face velocity control. (The face velocity is a measurement of air flow at the front, or face, of a fume hood; it is an indicator of effective hood containment. A face velocity of 100 feet per minute [fpm] is generally recommended.) Energy savings can be as high as 70%—by reducing the the maximum air flow (at full sash height) from 1000 cfm to the minimum of 300 cfm (with a closed sash)—in comparison to the energy use associated with CV hoods. To realize these energy savings, users must be trained in operating the hoods and must keep sashes closed except when the fume hoods are being loaded. Each fume hood has a dedicated VAV terminal unit to maintain the proper airflow at the fume hood regardless of the pressure fluctuations in the ductwork.

The building’s separate exhaust systems are listed in Table 2. The largest of them is the general building system.

**Table 2. Exhaust Systems in Building 50**

System	Type	Heat Recovery
General building	VAV	Yes
Fume hoods	VAV	No
Vivarium	CV	No
Smaller exhaust systems		
— BL3 labs	VAV	No
— Cage wash	VAV	No
— Fermentation labs	VAV	No
— Toilets	VAV	No

The equipment selected for the general building system uses 100% once-through air that is tempered in eight 50,000 cfm air-handling units (AHUs) equipped with energy recovery wheels. The animal vivarium needs a dedicated CV 50,000 cfm AHU without a heat wheel, because minute particles from the animal’s fur (dander) will accumulate on and foul the surfaces of the wheels. In general, exhaust exits the building 10 ft (3 m) above the roof at a discharge rate of 3000 fpm (914 mpm).

When the fume hoods are open, some room air is pulled through them and exhausted without heat recovery. When the fume hoods are closed, all except a minimum of bypass room air exhausts through the heat recovery wheels. For this reason, lab scientists will have to be educated about the importance of keeping fume hoods closed when the hoods are not in use. NIH Project Manager Frank Kutlak estimates that heat is not recovered from somewhat less than 20% of all exhaust air.

**VFD Motors and Pumps**

A variable-frequency drive or VFD is a solid-state device that varies the output frequency of standard 50 or 60 cycle input power to provide varying motor speeds. Since the power required to run the motors of fans and



Work stations and laboratory benches receive ample daylighting.

Don Prowler & Associates / PIX10304



pumps is proportional to the cube of its speed, large reductions in energy occur at lower speeds. Building 50 uses VFDs on all major motors and pumps. Developments in variable-frequency motor speed controls have increased reliability and lowered costs to the extent that VFDs are preferred for most applications. Though there are many advantages, VFDs also have higher initial costs, produce some noise, and can cause harmonic distortions of current flow.

The VFDs on the pump system operate in much the same way as they do on the VAV supply and exhaust fans, although in the pump system, the VAV terminal units are replaced by water control valves and cooling and heating coils. Differential pressure sensors in the water distribution piping system signal the VFDs to reduce the pump flows in response to a corresponding reduction in the cooling—or heating—coil control valves.

### **Energy Recovery**

The single most important and largest application of energy recovery in research facilities is in the laboratory exhaust systems. NIH selected desiccant energy recovery “heat wheels” as the method of heat recovery for general building exhaust. The heat wheels use heat-absorbing desiccant disks that rotate sequentially through, and transfer energy from, the building’s general exhaust to the supply air streams. The SEMCO wheels that were selected recover both sensible and latent energy and have higher rates of efficiency (at 60% to 70%) than other options for energy recovery.

The supply and exhaust air streams must be adjacent to each other to allow the wheel to rotate through both alternately; this requires that the mechanical penthouse be high enough to accommodate taller AHUs. A common concern about heat wheels is that there is potential for cross-contamination between the air streams. Because of this concern, NIH did not exhaust the containment devices (e.g., fume hoods, biologic safety cabinets) through the wheels. A separate, dedicated containment exhaust system is not manifolded into the general exhaust. The wheels have a self-purging system that has been proven to limit cross-contamination to 0.045%. A test conducted in August 2001 by the manufacturer, SEMCO, at Building 50 verified that the level of cross-contamination resulting from the carry-over of contaminants from the exhaust air stream into the building’s supply air stream was below the 0.045% limit.

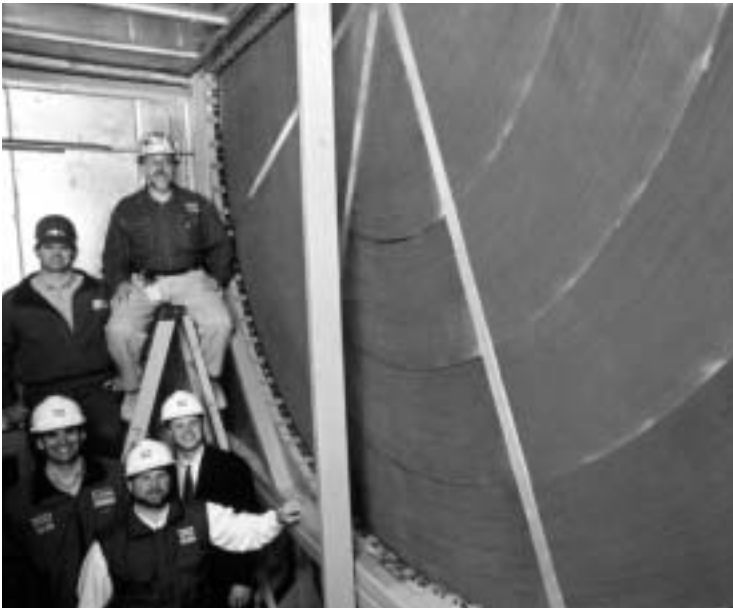
NIH completed a life-cycle cost study on all types of energy recovery systems. The desiccant energy recovery wheel concept proved to be the most cost-effective system. A major consideration is that the heat wheel is the only system that recovers latent as well as sensible energy, which is very important in the high-humidity summers of Bethesda. Ultimately, NIH accepted the use of an energy recovery wheel with several limitations, including these:

- The Division of Safety required a separate fume hood exhaust system, which results in a smaller volume (roughly 20% less) of air to the wheels and thus lower energy savings than would normally be obtained with the heat wheel.
- The Division of Engineering was concerned about insufficient building capacity if the heat wheels had to be abandoned in the future for any reason. Therefore, division staff required that the design and sizing of the mechanical system be done without considering heat wheel factors. The result is that NIH did not realize the benefits of downsizing the base building system design to take full advantage of energy recovery wheels.

### **Building Controls**

Direct digital controls with pneumatic actuators are used for the mechanical HVAC building systems. A Siemens Building Technologies building automation system provides a central computer station in the maintenance office with 3000 distinct control points and graphic displays of AHUs, exhaust fans, fume hoods, VAV terminal units, room temperatures, room differential pressures, pumps, heat exchangers, and central utility consumption.

Alarms and maintenance reminders are displayed automatically as well as transmitted to a central campus engineering facility for remote off-shift monitoring. This



Ernie Branson, NIH/PIX03663

The Louis Stokes Laboratories design and construction team, with one of the eight SEMCO desiccant energy wheels used in the building.



enables the engineering maintenance staff to control, track, and monitor all equipment throughout the building. A second read-only computer monitor in the animal facility office allows the veterinarians to monitor and keep records of conditions in the vivarium.

**Lighting**

NIH did a good job of daylighting both the laboratories and the break rooms, and the quality of the light there is excellent. Building 50 also features the latest in lighting technology. All the fluorescent light fixtures use T-8 lamps and electronic ballasts. The building uses light-emitting diode (LED) exit signs and motion sensors in break rooms, conference rooms, and bathrooms.

The programmable lighting control system for the building also contributes significantly to total energy savings. The lighting for the entire building can be programmed to shut off at a predetermined time. This can also be manually overridden by users who are working late. Lighting is estimated to consume about 11% of the energy used in this lab facility.

**Other Issues**

The veterinary staff requested that the vivarium be provided with a dedicated air handler. This request amounted to a need for two dedicated air handlers, since a vivarium cannot take the risk of relying on only one air handler but rather must have a redundant or backup unit to use during emergencies and during routine servicing of the primary unit. A redundant elevator was also requested. In both cases, no rules specified by the American Association for Accreditation of Laboratory Animal Care require either dedicated air handlers or dedicated redundant elevators.

The design team therefore provided the dedicated vivarium air handler but not a redundant one. Instead, they backed up the vivarium air handler by manifolding it into the lab air handlers, thus saving several hundred thousand dollars and, even more important, several hundred square feet of floor space. A backup to the primary vivarium elevator was provided by installing a back door leading to the building’s freight elevator.

**Commissioning Process**

The construction management team established a formal commissioning phase with an outside professional commissioning consultant (Facilities Dynamics of Columbia, Maryland) through the construction quality manager. A commissioning committee, which includes staff from many NIH Office of Research Support (ORS) groups, has run the building through hundreds of functional performance tests to verify that the installations conform to all contractual requirements.

**Table 3. Louis Stokes Laboratories Building Metrics**

System	Key Design Parameters	Annual Energy Usage (based on design data)
Ventilation (sum of wattage of all the fans and the exhaust fans)	1.25 W/cfm <sup>(1)</sup> 1.36 cfm/gross ft <sup>2</sup> <sup>(2)</sup> (2.15 cfm/net ft <sup>2</sup> )	30 kWh/gross ft <sup>2</sup> (48 kWh/net ft <sup>2</sup> ) <sup>(3)</sup>
Cooling plant	1900 tons	15.0 kWh/gross ft <sup>2</sup> <sup>(4)</sup>
Lighting	1.6 W/gross ft <sup>2</sup>	7.25 kWh/gross ft <sup>2</sup> <sup>(5)</sup>
Process/Plug (receptacles)	3 W/gross ft <sup>2</sup> 5.7 W/gross ft <sup>2</sup> (lab equipment)	15.2 kWh/gross ft <sup>2</sup> <sup>(6)</sup>
Heating Plant	12, 253 MBH heating plant capacity	Not available
<b>Total</b>		67.45 kWh/gross ft <sup>2</sup> /yr for electricity only  230,139 Btu/gross ft <sup>2</sup> /yr for electricity only <sup>(7)</sup>

**Notes:**

- [101 Hp (supply) + 115 Hp (exhaust)] x 746 W/hp ÷ [50,500 cfm (supply) + 77,500 cfm (exhaust)] = 1.25 W/cfm
- Total cfm required for all 6 floors is 400,000; 400,000/294,532 gross ft<sup>2</sup> = 1.36 cfm/gross ft<sup>2</sup>; 400,000 cfm/186,062 net ft<sup>2</sup> = 2.15 cfm/net ft<sup>2</sup> .
- (1.25 W/cfm x 1.36 cfm/gross ft<sup>2</sup> x 8760 hours) x 2/1000 = 15 kWh/gross ft<sup>2</sup> (multiplied by 2 to account for both supply and exhaust).
- 0.8 kW/ton (estimate) x 1900 tons x 2890 hours / 294,532 gross ft<sup>2</sup> = 15.0 kWh/gross ft<sup>2</sup> (assumes cooling runs 33% of the hours in a year). Chilled water is supplied from a central plant.
- 1.6 W/gross ft<sup>2</sup> x 4534 hours /1000 = 7.25 kWh/gross ft<sup>2</sup> (assumes lights are on 87.2 hrs/week); 1.7 VA/gross ft<sup>2</sup> x 95% power factor = 1.6 W/gross ft<sup>2</sup>.
- 8.7 W/gross ft<sup>2</sup> x 1752 hours/1000 = 15.2 kWh/gross ft<sup>2</sup> (assumes plugs and lab equipment operate 20% of the time and 9.6 W/net ft<sup>2</sup> x 0.9 power factor = 8.7 W/gross ft<sup>2</sup>).
- Estimated data are presented in site Btu (1 kWh = 3412 Btu). To convert to source Btu, multiply site Btu for electricity by 3. Note: Bethesda has approx. 4704 heating degree days and 1137 cooling degree days (using data for Baltimore).

**Measurement and Evaluation Approach**

Building 50 will be the first building at NIH in which all utilities are fully metered, so the ORS Division of Engineering Services facilities management staff will be able to accurately record the building’s energy usage.



## Summary

Because of all the energy-saving systems incorporated into the Louis Stokes Laboratories, it is estimated that this building will require in the range of 40% less energy than a traditional research laboratory facility consumes. The laboratory also demonstrates the use of desiccant energy recovery heat wheels and VAV supply and exhaust system in a laboratory environment. In addition, the NIH scientists will enjoy the amenity value of natural daylighting in their workspaces, while the government receives a \$2 million efficiency rebate from the local utility provider. These benefits are all consistent with the objectives of the Laboratories for the 21st Century program.

## Acknowledgements

This case study would not have been possible without the contributions of Frank Kutlak, R.A., NIH Project Officer. Frank has been a key participant in the Laboratories for the 21st Century program almost since its inception, and he has made numerous valuable contributions. Nancy Carlisle of NREL also contributed to this case study.

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