



LABORATORIES FOR THE 21ST CENTURY: CASE STUDIES

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WHITEHEAD BIOMEDICAL RESEARCH BUILDING AT EMORY UNIVERSITY, ATLANTA, GEORGIA

Introduction

The eight-story Whitehead Biomedical Research Building, which was completed in 2001, is the largest of its kind in the southeastern United States; it has incorporated many energy- and water-efficient features. This new building at Emory University supports three science departments within the School of Medicine—Cell Biology, Genetics, and Physiology. And an entire floor is devoted to interdisciplinary programs for the Departments of Neurology, Neurosurgery, Pathology and Laboratory Medicine, Psychiatry, and Behavioral Sciences.



U.S. Department of Energy
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This case study of the Whitehead Research Building is one in a series produced by *Laboratories for the 21st Century*, a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Geared toward architects and engineers who are familiar with laboratory buildings, the case studies exemplify the “Labs 21” approach, which encourages the design, construction, and operation of safe, sustainable, high-performance laboratories.

The energy and water efficiency strategies incorporated in the Whitehead Research Building’s design and construction reflect a significant commitment to environmental stewardship on the part of both Emory University and the design team. Emory University’s new buildings are guided by a comprehensive master plan that emphasizes sustainable design practices, which include creating a pedestrian-friendly campus that replaces cars and concrete with greenspaces and walkways. This facility was one of the first buildings at Emory to incorporate new architectural guidelines while integrating the design into the context of a historic campus.



“We may be making just a small dent in local environmental problems in the state of Georgia, but what if everybody did the same?” John Wegner, Emory University Campus Environmental Officer



These are some of the building’s many sustainable, high-performance features:

- **Energy recovery**—The energy recovery system is made up of four desiccant cooling enthalpy wheels, each 20 feet (ft) in diameter, that use air exhausted from the facility to preheat the outside air in winter and to pre-cool outside air in summer before it is drawn into the building.
- **Condensate recovery for cooling towers**—Air-conditioning condensate water is piped from the air-handling units (AHUs) and chilled water coils back into nearby cooling towers for use as make-up water. This diverts an estimated 2.5 million gallons of condensate water per year from the county’s sanitary sewer and reduces municipal water consumption at the central plant. The resulting savings could supply 100 people in the United States with their daily water needs for 125 days of the year.
- **Rainwater harvesting for irrigation**—Storm water from the roof and the plaza is collected into an underground storage vault and reused for irrigation.

- **Natural lighting and lighting controls**—Approximately 90% of regularly occupied spaces have large windows for daylighting, saving energy that would otherwise be consumed by the electric lights, many of which are controlled by photo sensors and motion detectors.

The building received a Leadership in Energy and Environmental Design (LEED™) silver rating in 2002 from the U.S. Green Building Council. It also won an Energy User News “Best New Project” Award in 2002, and it received an Honorable Mention in 2003 from *Environmental Design + Construction* magazine for “Excellence in Design.” The additional cost incurred to achieve a LEED silver rating was about \$990,000, or 1.5% of the building’s total construction cost. Emory’s savings in energy costs alone over the next decade will cover the additional first cost.

Project Description

The Whitehead Biomedical Research Facility is an eight-story, 325,000 gross ft² (212,264 net ft²) laboratory building that houses special facilities for tissue culture and a vivarium. It was completed in October 2001, one month ahead of schedule, at a total construction cost of \$65 million, or \$200/gross ft². The facility was designed by Hellmuth, Obata + Kassabaum, Inc. (HOK) of Atlanta, Georgia. The structural engineers were Standley D. Lindsey of Atlanta, and the mechanical, electrical, plumbing and fire-protection engineers were Nottingham, Brooke and Pennington of Macon, Georgia. The Whitting-Turner Contracting Company of Atlanta was the general contractor and construction manager.

Layout and Design

The building includes 150 faculty offices and 150 laboratory modules built around the “open lab” concept. This concept calls for large, flexible laboratory spaces and fewer walls, resulting in a building designed for greater interaction and better flow among researchers. Dry benches are along the windowed walls. Corner break rooms with dry-erase wall coverings were designed to foster collaboration. The largest wing of the building is oriented along an east-west access, which allows natural light to enter the building from the north or south. The facility supports both Biosafety Level (BL)-2 and BL-3 research activities.

The basic planning module for the labs measures 10 ft x 39 ft. Laboratories are organized in open groups of 10 modules each. The design allows for increases or decreases in occupied square footage for individual research programs, in response to changing program



needs. This adjustment is accomplished by simply connecting individual laboratory modules via openings in shared partitions. The large, open labs also allow multiple research groups to work very near each other with minimal separation. The interdisciplinary interaction benefits all of the building’s occupants.

Each open lab grouping has its own controls for lighting; heating, ventilation, and air-conditioning (HVAC); and piping. Controls for these services are located outside the lab. In addition to designing standardized modules for the labs, the piping and HVAC are also modular in design to allow the lab units to adapt quickly and respond to changes in technologies, equipment, processes, and techniques. The flexibility offered by this modular approach allows Emory to change labs without affecting adjacent spaces. The enhanced laboratory design greatly increases the research efficiency of departments such as Cell Biology and Physiology, which had been housed in buildings constructed in the 1920s before the new facility was built.

The third-floor plan is shown in Figure 1. A breakdown of space by function is shown in Table 1.

Utility Servicing

Figure 1 depicts the duct and pipe shafts and lab piping closets; this illustrates how utilities are integrated into the building. Much of the work in the labs, up to 24 hours per day, is done on the bench top rather than in fume hoods. So, building energy loads are driven by the air change rate, instead of by the number of fume hoods.

Table 1. Whitehead Biomedical Research Building Space Breakdown (Net ft², unless otherwise noted)

Function	Size (ft ²)	Percentage ⁽¹⁾
Labs (BL-2 and BL-3) and lab support space	148,000	70%
Office and program support	35,600	17%
Environment, health, and safety space	5,000	2%
Vivarium	23,664	11%
Total net ft ²	212,265	100%
Other ⁽²⁾	112,735	
Total gross ft ²	325,000	

Notes:

1. The percentage shows a breakdown of net ft² only. Net ft² equals gross ft² minus “other.”
2. “Other” includes circulation, toilets, stairs, elevator shafts, mechanical and electrical rooms and shafts, and structural elements like columns. The net-to-gross-ft² ratio is 0.65.

The HVAC system was designed to operate at constant volume and to include energy recovery; four enthalpy wheels, each one 20 ft in diameter, are used. The building has a general exhaust system and a separate fume hood exhaust system. Only the general exhaust goes through the energy recovery wheels.



Figure 1. Third-floor plan of Whitehead Biomedical Research Building at Emory University



The general labs were designed for a ventilation rate of 10 air changes per hour (ACH). The building has 69 chemical fume hoods. Each of the fume hoods uses a valve to keep the airflow constant in case the duct static pressure varies. The building also includes 16 exhausted biosafety cabinets. The cabinets in the BL-3 area connect to the fume hood exhaust.

The vivarium was first designed for 15 ACH but was redesigned to 10 ACH when ventilated cages were selected for use in it. However, because the cages were not scheduled to be available when the building opened, the vivarium was redesigned back to 15 ACH. The cages were added later. A portion of the vivarium's exhaust, from rooms containing general animal housing, goes through the general exhaust. Exhaust air from animal rooms that contain contaminants or pathogens goes through the fume hood exhaust system.

The vivarium exhaust represents about 4% of the total volume of air exhausted through the energy recovery wheels. At one point, however, it was found that the vivarium exhaust didn't mix as well as expected with the general exhaust, and some odors were being recirculated back into the building. The lesson learned from that experience was to reduce the ratio of vivarium exhaust to general exhaust even further, to about 2%.

Chilled water is supplied to the building from a chilled water plant. The tonnage of cooling required was computed by allowing credit for the heat recovery from the enthalpy wheels, with one wheel offline for service at or near the peak design date. A central plant provides the building with steam for heating.

Design Approach

From the start, the project design reflected a commitment to sustainable design practices. However, achieving the LEED silver certification did not become a design goal until a few months after construction began in March 1999, when Emory University decided to make LEED certification mandatory for all new campus projects, starting with the Whitehead Research Building. Typically, planning for LEED certification occurs during the early stages of the design process. In this case, however, the design team was already sensitive to the need to save energy and water and to integrate the building into an overall campus plan emphasizing pedestrian movement. So, the design team needed to incorporate only a few things to achieve a silver rating.

The project delivery method was Construction Manager At-Risk, with a fast-track, phased design document process. After the construction of the first and the second packages (the foundation and structure) of this

project were well under way, cost reports showed that the completed project would be \$6 million over budget. At that point, the project team—including the designers, construction manager, and owner—went through an intense value engineering phase that lasted 2 months. During that phase, the team kept its focus on the life-cycle cost of the project. They worked hard to protect the features of the building that made good business sense for the owner in the long run, even though those features added to the first cost. At the end of the value engineering phase, the project team was successful in bringing the project within striking distance of the budget.

Technologies Used

The building is on a site that had been developed previously, increasing density without losing green space. A greenhouse already on the site was relocated to another site on campus instead of being demolished. The new building is served by Emory's alternative transportation system, with no net increase in parking and a reduction in local vehicle emissions. To support this and other new projects, Emory built a parking garage a few miles from the campus. A new shuttle road served by alternatively fueled vehicles—both compressed gas and electrical ones—allows Emory to ferry people back and forth from the parking area to the campus.

The university also has a policy that assures no net loss of the tree canopy. This means that, for each tree removed, one tree is planted elsewhere on campus.

Energy Efficiency

The primary strategy for energy efficiency is to use the four 20-ft-diameter enthalpy wheels for energy recovery. The enthalpy wheels recover heat energy from exhaust air and use the air exhausted from the facility to preheat outside air in the winter and to precool outside air in the summer. The wheels are in a mechanical penthouse room on the top floor of the building; this mechanical penthouse is hidden from view by a sloped roof. The air intake is below the eave of the roof. An exterior view of the building is shown in the photograph on page 1.

The added first cost of the heat recovery system was \$450,000, with a simple payback of about 4 years. The mechanical engineer convinced the design team of the usefulness of this feature, and the owner had the foresight to see that this was the right decision in the long run. Their efforts helped to keep the wheels in the project during the cost-cutting phase.

Return air from clean zones, such as offices, is mixed back into the supply air so that supply air is approximately 75% outside air to all zones. This strategy saves on the amount of air that needs to be conditioned.

An energy analysis was performed to compare the building as designed with a base case building meeting American Society of Heating, Refrigerating, and Air-Conditioning Engineers/Illuminating Engineering Society of North America (ASHRAE/IESNA) standard 90.1-1999. Expected annual savings include 2161 MBtu of heating fuel and 3.4 million kWh of electricity, or \$167,730 in energy costs. This takes into account the savings from daylighting controls and high-efficiency equipment. And it translates into a 22.2% overall energy savings, when compared with the base case.

System design decisions were made on a life-cycle cost basis, and a “value management” process was employed to ensure that cost-reduction decisions did not reduce the facility’s long-term value to the university. For the energy recovery system alone, the internal rate of return on a \$450,000 investment yielding \$136,028 annually over 10 years would be 28% (this assumes no escalation in utility costs over that time). If costs and benefits of other efficiency measures were taken into consideration, the actual rate of return relative to a code-compliant facility would be significantly greater.

The ventilated cages used in the vivarium provide several opportunities for energy and material savings and health benefits to occupants. The system used in the Whitehead Building provides supply and exhaust air directly to and from each individual cage. And the system allows a reduction in the ventilation air rate from 15 ACH to 10 ACH. In new construction, this could allow a reduction in the size of the fans serving the vivarium. The ventilated racks also keep the corncob bedding drier, so that it must be changed only every 14 days rather than every 7 days. The ventilated racks provide health benefits for workers and reduce the spread of allergens.

Daylighting and Lighting

Ninety percent of the building’s lab and office spaces line the perimeter and include windows to the outside. Thus, the vast majority of occupied rooms receive natural light during the day. The building’s perimeter electric lighting system is tied to an on/off switch controlled by a photocell (with manual overrides) to control the row of lights parallel to the window. These lights are automatically switched off when there is adequate natural lighting.

Each 2500-ft² zone in lab areas has six 3-way switches to control lights. Individual offices and small rooms use motion detector lighting controls. The lighting inside the building uses T-8 lamps with electronic ballasts in two-lamp, 1x4 recessed parabolic fixtures located directly over each bench. The lighting level at bench top is 75 foot-candles.

Water Efficiency

Emory University incorporated several water-saving measures into this project. These include storm-water harvesting for irrigation, a condensate recovery system for make-up water in cooling towers, and advanced cage-washing techniques.

The building’s storm-water harvesting system captures water from the roof and the outdoor plaza and moves it to a large retention vault beneath the plaza. The water is then filtered and reused for site irrigation. Fulton County required Emory to build a retention vault to slow down the runoff of storm water from the roof and the site. When they decided to go for LEED certification, the Emory design team made the underground retention vault 3 feet deeper so it would hold about 70,000 gallons of water. They also added a filter, a pump, and a bit of piping to connect this catchment area into the site’s irrigation system. Figure 2 shows the retention vault under construction.

In addition, the design team recognized that the air-conditioning system would create a tremendous amount of condensate water. So, they decided to pipe the condensate from the AHUs and chilled water coils back into nearby cooling towers for use as make-up water. This system not only conserves water, it also diverts an estimated 2.5 million gallons a year from the county’s sanitary sewer system, saving energy and money as well.

The vivarium includes a state-of-the-art, automated cage-washing system. The cage washer, which was manufactured in Finland, is one of the first ones installed in the United States. It saves energy, water, and chemicals by recycling water through four stages of cleaning using a counter-current rinsing process. In counter-current rinsing, the flow of rinse water for cage washing is the oppo-



Figure 2. Retention vault





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Figure 3. Robotics used in cage washing operation

site of that of the workflow. In other words, the cleanest water is used only for the final rinsing stage; water for early rinsing tasks, in which the quality of rinse water is not as important, is water that was previously used in the later stages of rinsing operations. An automated process using robotics disposes of the dirty bedding, feeds the cages through a washer, fills the clean cages with clean bedding, and replaces cages in the racks. This has eliminated much of the manual labor associated with this task. Figure 3 shows the robotics.

A central plant system is used for cooling. The cooling load, and thus the amount of chilled water needed, is reduced approximately 20% by the operation of the enthalpy wheels.

Indoor Environmental Quality

To protect the building's indoor air quality, paints and adhesives with low levels of volatile organic compounds, or VOCs, were used, and it has been designated a nonsmoking facility. During construction, a management plan was implemented to prevent the contamination of building materials by water, dirt, and other sources of pollutants. Before the staff moved in, the office areas were flushed with 100% outside air.

Materials

The building materials incorporate products (such as lab counters) that are manufactured using post-consumer and post-industrial waste. In addition, the construction featured materials that are manufactured locally, reducing energy used for transportation. Emory also followed a construction recycling plan. They recycled 300 tons of metal and saved about \$20,000 by being conscientious about recycling.

Measurement and Evaluation Approach

Meters were installed at the main switchboard to track electrical loads off individual feeder lines as well as to measure the use of steam and water, including chilled water. Electric power and steam usage is reported in Table 2.

Commissioning

Emory's standard approach is to commission all new buildings before they open for business. This includes commissioning all the building systems to ensure that they are operating in the intended ways. The owners believe that, while commissioning improves the efficiency of most buildings, it is especially important for laboratory buildings, which use a large amount of energy and have special safety requirements as well as sophisticated control systems, like fume hoods.

Building Metrics

In Table 2, data on annual energy use that was estimated from design parameters is compared with actual metered data summed from three electric meters and metered steam data. The metered data were tabulated for 2 years for comparison purposes and were similar in both years; the table shows annual data for May 2003 through April 2004. Metered data are 20% lower than the estimate. This is generally the case in laboratories featured in Labs 21 case studies because the estimates are usually conservative, and they take into account only very general usage information. Since the cooling load at the central plant was not accounted for by the building's electric meters, an estimate for cooling was added to the data for actual energy use measured at the building. Water use at this facility was measured at 11,715,000 gallons per year.



Table 2. Whitehead Biomedical Research Center Building Metrics

System	Key Design Parameters	Annual Energy Usage Estimate (based on design data)	Annual Energy Use (based on measured data)
Ventilation (sum of wattage of all the supply fans and all the exhaust fans)	Supply = 1.0 W/cfm Exhaust = 1.25 W/cfm Total = 1.13 W/cfm ⁽¹⁾ (1.0 cfm/gross ft ² ; 1.5 cfm/net ft ² and 2.1 cfm/gross ft ² of labs) ⁽²⁾	19.8 kWh/gross ft ² ⁽³⁾	NA
Cooling plant	2300 tons, 1.0 kW/ton	20.4 kWh/gross ft ² ⁽⁴⁾	NA
Lighting	1.6 W/ft ² average	7.25 kWh/gross ft ² ⁽⁵⁾	NA
Process/Plug	11 W/net ft ²	32.4 kWh/gross ft ² ⁽⁶⁾	NA
Heating plant	Not available	Not available	68,298,447 pounds of steam
Total		79.85 kWh/gross ft ² /yr (estimate based on design data for electricity only) 272 kBtu/gross ft ² /yr for electricity only	42.90 kWh/gross ft ² /yr for electricity only (based on metered data from 05/03 – 04/04) Since cooling is provided by a central plant, the estimate of 20.4 kWh/gross ft ² /yr is added back in Total electrical energy = 63.3 kWh/gross ft ² /yr (222.6 kBtu/gross ft ² /yr) Steam = 210 kBtu/gross ft ² /yr 432.6 kBtu/gross ft ² for electricity, cooling (est.) and steam

Notes:

1. W/cfm for supply air = 910 hp x 746 W/hp/681,000 cfm (supply) = 1.0 W/cfm; for exhaust air = 530.5 hp x 746 W/hp/317,040 cfm = 1.25 W/cfm; average = 1.13 (based on nameplate rating data).
2. 317,040 cfm (total cfm based on exhaust)/212,265 net ft² = 1.5 cfm/net ft²; 317,040 cfm/325,000 gross ft² = 1.0 cfm/gross ft²; 317,040 cfm/148,000 net ft² of labs = 2.1 cfm/net ft² of labs.
3. 1.13 W/cfm x 1.0 cfm/gross ft² x 8760 hours x 2/1000 = 19.8 kWh/gross ft² (30.5 kWh/net ft²).
4. 1 kW/ton x 2300 tons x 2890 hours/325,000 gross ft² = 20.4 kWh/gross ft² (assumes cooling runs 33% of the hours in a year).
5. 1.6 W/gross ft² x 4534 hours/1000 = 7.25 kWh/gross ft² (2.46 W/net ft² x 0.65 = 1.6W/gross ft²) (assumes lights are on 87.2 hours/week).
6. 7.71 W/gross ft² x 0.80 x 5256 hours/1000 = 32.4 kWh/gross ft² (11 W/net ft² x 0.65 = 7.71 W/gross ft²) (assumes that 80% of all equipment is operating 60% of the hours in a year).
7. Estimated data are presented in site Btu (1 kWh = 3412 Btu). To convert to source Btu, multiply site Btu for electricity by 3. Note: Atlanta has approx. 3089 heating degree-days and 1611 cooling degree-days (based on weather data for Atlanta, GA).

Summary

The Whitehead Biomedical Research Building design team was sensitive to the need to save energy and water and to integrate the building into an overall, pedestrian-friendly campus plan. These became key factors in the success of this building as a high-performance laboratory. The mechanical engineer advocated the use of energy recovery wheels early in the process, and they are integrated effectively into the building’s architecture under a sloped roof. The design team also strongly emphasized water efficiency by incorporating an underground water storage vault for storm water to use in irrigating the site, and by piping air-conditioning condensate from the air-handling units and chilled water coils back into nearby cooling towers for use as make-up water.

Emory University’s strong commitment to sustainability is evident in building designs that are guided by a comprehensive master plan for the campus that includes replacing cars and concrete with green spaces and walkways. Emory’s tree canopy policy also makes it a leader in the university community for environmental responsibility. In addition, the university requires all new buildings to achieve a LEED silver certification rating.



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