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Innovations Help Lab Achieve Low Energy Use

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At the OHSU Knight Cancer Research Building 650 elite, multidisciplinary scientific researchers work to find cures for cancer.

The Oregon Health & Science University Knight Cancer Research Building in Portland, Ore., houses 650 elite, multidisciplinary scientific researchers who find cures for cancer. The net 260,000 ft^2 (24 155 m^2) building, which includes 75,000 ft^2 (6968 m^2) of wet lab space and 25,000 ft^2 (2322 m^2) of computational lab space, achieved an EUI of 95 kBtu/ft^2·yr (1083 MJ/m^2·yr) for the first year of operation, in part by lowering the minimum speed of lab exhaust fans during calm wind conditions. Other energy reducing strategies include an innovative way to provide makeup air that increased ventilation in the offices and reduced reheat energy in the labs. This project received the 2021 ASHRAE Award of Engineering Excellence.

The LEED Platinum building houses a gathering lobby, large auditorium and retail restaurant on the main level. Floors 2 through 5 are split, with offices on the northern half and laboratory spaces on the southern half. Floors 6 and 7 have a smaller footprint and house offices and meeting rooms. Two basement levels include parking and 15,000 ft^2 (1,394 m^2) of laboratory space.

Energy Efficiency

Baseline and proposed buildings were simulated with the Department of Energy's eQuest Version 3.65 software following the modeling guidelines of ASHRAE/IESNA Standard 90.1-2007, Appendix G.

Building geometry was based on the architectural plans and was modeled identically between baseline and proposed cases. All operational schedules, occupancy profiles and miscellaneous receptable equipment were also identical between models.

Lighting was modeled via the space-by-space method using typical ASHRAE/IESNA Standard 90.1-2007 space types. For the proposed model, actual fixture wattage was tabulated for each space, and lighting power density for each space type was determined. Occupancy sensors are installed in all occupied spaces, except for stairwells, allowing for a 10% lighting power credit for all such spaces, with the exception of conference rooms.

Daylighting is directly modeled in the laboratories on the south façade as well as some northern offices and conference rooms. Dimming is controlled to a 50 fc illuminance setpoint, down to a minimum of 20% lighting power.

The building uses centralized service hot water systems that provide 140°F (60°C) water for domestic and industrial (e.g., laboratory sinks) applications. A pair of 94% efficient condensing gas water heaters are installed for each of the domestic and industrial systems. The domestic water system assumes a 45% demand savings from low-flow fixtures, including 0.5 gpm (1.9 L/min) metering sensor faucet lavatories and 1.5 gpm (5.7 L/min) showers. Flow rates for industrial hot water were modeled identically, as were recirculation pumps and auxiliary electric booster heaters serving remote pressure zones.

The building HVAC system includes four central air-handling units (AHU): AHU-1 serves the basement laboratory spaces, AHU-2 serves laboratory spaces on Floors 2 through 5, AHU-3 serves office and non-lab spaces, and AHU-4 is dedicated to the auditorium. AHUs 1 and 2 are 100% outdoor air units. Heat recovery from the variable speed laboratory exhaust system is used to pretreat outdoor air serving AHUs 1, 2 and 3 via a run-around loop.

The building hydronic system (*Figure 1*) includes two high efficiency water-cooled centrifugal chillers, plus one water-cooled heat recovery chiller. The heat recovery chiller preferentially rejects heat to the building's heating water loop,

PHOTO 1 Lab exhaust heat recovery unit adjacent to boiler flues on the roof.

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transferring heat from high density equipment rooms and laboratory spaces to perimeter office spaces that may need heating. Additional heating water is provided by 93% efficient condensing boilers.

In addition to using ASHRAE/IESNA Standard 90.1-2007 as a baseline, the design team wanted to compare the proposed building's energy use to similar buildings currently in operation, namely other research laboratories in the Pacific Northwest. The design team used the International Institute for Sustainable Laboratories (I^{2}SL) benchmarking data to establish a baseline EUI for similar laboratories of 265 kBtu/ft^2·yr (3009 MJ/m^2·yr). From this, the team was able to set an Architecture 2030 Challenge target of 116 EUI kBtu/ft^2·yr (1317 MJ/m^2·yr).

The results of the ASHRAE/IESNA Standard 90.1-2007 baseline, I^{2}SL baseline, Architecture 2030 Target and designed building are summarized in *Figure 2*.

The designed building had an energy use intensity of 107 kBtu/ft^2·yr (1215 MJ/m^2·yr), 43% less energy use compared to the Standard 90.1-2007 baseline EUI of 189 kBtu/ft^2·yr (2146 MJ/m^2·yr). The designed building also meets the Architecture 2030 Challenge.

Actual energy use was even better than predicted, totaling 95.4 kBtu/ft^2·yr (1083 MJ/m^2·yr) for the first year of operation. The data for the first year of operation was taken between September 2018 and September 2019, prior to the COVID-19 pandemic, and captures an occupied and fully functional building.

Indoor Air Quality

The primary method for maintaining a safe environment in the lab spaces was the use of fume hoods, biosafety cabinets and flammable and corrosive storage cabinets. These separate any potentially harmful chemicals from the occupant breathing zone. In addition, the owner's Environmental Health and Radiation Safety group required that lab spaces maintain 6 air changes per hour (ach) while occupied and 4 ach when unoccupied. All the air from the lab spaces is exhausted out of the building and not recirculated. The high exhaust rates required within the laboratory spaces necessitate a large amount of outdoor makeup air, which can be very energy intensive to condition and distribute.

Fortunately, the design team came up with an innovative method of providing makeup air that increased the ventilation rate of the office space and reduced reheat energy in the lab spaces. This was achieved by introducing a portion of the makeup air into the office spaces adjacent to the labs and using transfer fans to move the excess air from the office space into the labs. A schematic of this cascading air strategy is shown in *Figure 3*.

FIGURE 1 Hydronic system.

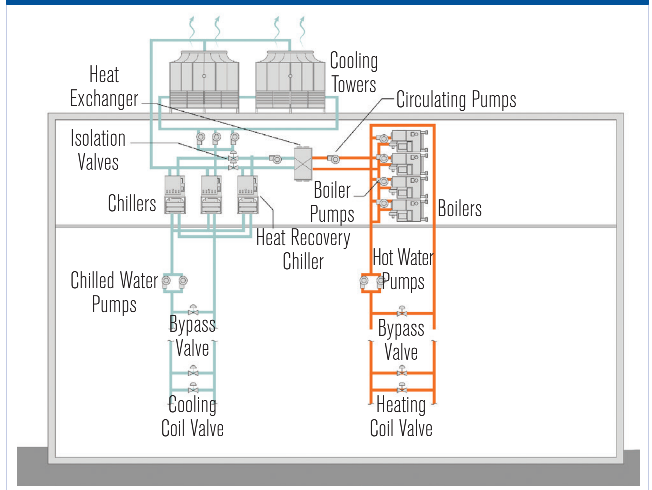
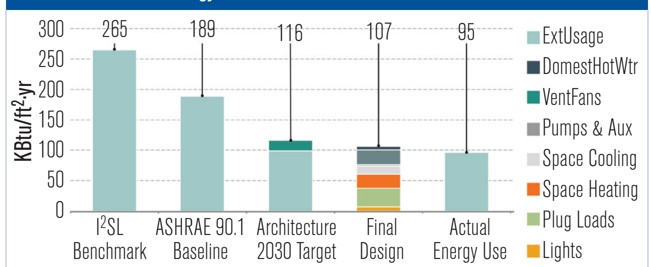


FIGURE 2 Modeled energy.



The following ASHRAE Standard 62.1-2010 ventilation criteria were evaluated for the project: science laboratories require 10 cfm/person (4.7 L/s), plus 0.18 cfm/ft^2 (0.9 L/s·m^2); while offices require 5 cfm/person (2.4 L/s), plus 0.06 cfm/ft^2 (0.3 L/s·m^2).

Applying this across the lab and office spaces in the building, the required occupied ventilation rate is approximately 38,000 cfm (17 934 L/s). A ventilation effectiveness of 0.8 was used for office spaces due to ceiling supply of warm air with ceiling return, and a ventilation effectiveness of 1.0 was used in lab spaces due to the high equipment loads and relatively low supply air temperatures.

The lab air change rates directed by the owner require nearly 60,000 cfm (28 317 L/s) of exhaust and subsequent makeup air. With the makeup air volume so much higher than the required ventilation rates, the design team looked for ways this excess ventilation could benefit building occupants.

By controlling where the excess ventilation air is introduced into the building, the team was able to increase ventilation rates throughout the building and thus increase the indoor air quality not only in the labs, but also in the adjacent office spaces. Because the laboratories require continuous exhaust even during unoccupied hours, the cascading air system results in a thorough flush out of the office spaces every night.

The added benefit of the cascading air strategy is the reduced amount of reheat energy needed to condition the lab spaces. Because of the high air change rates required in laboratories, many of the spaces would become overcooled if not for a significant amount of reheat energy. The air being transferred into the labs from the adjacent office spaces reduces the reheat demand by using internal heat loads of the office space to warm up the air prior to being transferred into the labs. It is estimated that fan energy and reheat reductions total 25 kBtu/ft^2·yr (284 MJ/m^2).

The project used ASHRAE Standard 55-2010 criteria to meet thermal comfort targets. The Center for the Built Environment Thermal Comfort Tool was used with the following summer and winter conditions to verify compliance with ASHRAE Standard 55-2010:

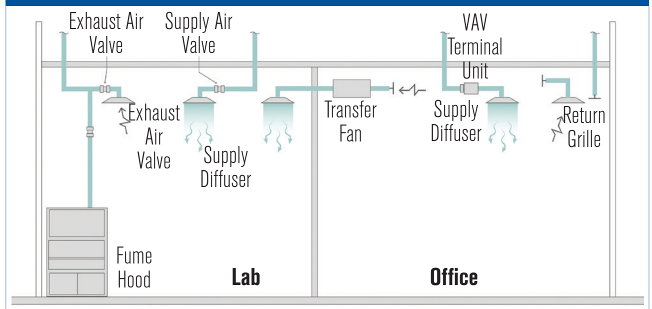
- Activity level: 1.4 met;
- Space temperature: 72°F (22°C);
- Clothing thermal resistance values (clo) assumed: 1 (winter)/0.5 (summer);
- Radiant thermal control: N/A;
- Air velocity: 20 fpm (0.1 m/s); and
- Humidity/condensation: 50% relative humidity.

A post-occupancy survey recently conducted shows that 90% of building occupants who responded to the survey are “somewhat satisfied,” “satisfied” or “very satisfied” with the air quality in the building and only 3% are “somewhat dissatisfied,” “dissatisfied,” or “very dissatisfied.”

Innovation

Safety is a primary goal within any laboratory environment. Fume hoods, chemical storage cabinets and high air change rates are used to maintain a safe indoor environment. To ensure a safe outdoor environment around the building, lab exhaust discharge locations and velocities were studied using wind tunnel testing. Based on actual locations of lab exhaust fans, outdoor air intakes and occupied outdoor areas, the wind study informed the design team of the minimum discharge velocities required at specific wind speeds and directions. In general, the calmer the wind, the lower the discharge velocity needed to ensure the exhaust plume extends a safe distance from the building (*Figure 4*).

FIGURE 3 Cascading air strategy.



An anemometer was installed on the roof of an adjacent building, which is taller than the Knight Cancer Research Building. The anemometer communicates with the HVAC controls system and provides real-time wind speed and direction, which is used to reset the minimum speed of the lab exhaust fans.

Fan speed has a cubed relationship to energy, which means significant potential to reduce energy use exists if fans are allowed to operate at slower speeds. Being able to turn down the lab exhaust fans during calm conditions is estimated to reduce the overall energy use of the building by 10 kBtu/ft^2·yr (114 MJ/m^2·yr) without compromising the safety of the occupants in or around the building.

Maintenance + Operation

Having the owner and building engineer involved during the design phase kept the team focused on how the building was going to be operated and maintained. The owner, Oregon Health & Science University (OHSU), owns and maintains many buildings on their campus, and as a result they have very vibrant design and construction and building operation groups that provided input into the project throughout the design. Control sequences that have been tested and proven on previous projects were implemented, and locations of service valves, filters and disconnects were scrutinized. Thorough commissioning of mechanical, electrical, plumbing (MEP) systems was performed prior to occupancy.

One important component of operating and maintaining a high efficiency building is a robust controls system that provides information on how the MEP systems are operating. The building automation system installed at the Knight Cancer Research Building includes energy and water meters on major equipment and systems as well as programing that sums overall energy use of the entire mechanical plant (*Photo 2*). Real-time and historical data on the performance of chillers, boilers, pumps and fans are gathered and stored by the building automation system.

This information is very useful to the savvy building operator who can make setpoint or operational adjustments and see the results of those actions immediately. Buildings can be very dynamic in operation, and as much as we try to accurately model how they will operate over months or years, it is the real-time feedback that can be a valuable tool to the building operator in maximizing system efficiency.

During the first year of operation, the owner got to put the HVAC systems to the test and reported that everything is operating smoothly.

Cost-Effectiveness

The project used an integrated project delivery (IPD) method to maximize the creativity of the design, increase design and construction efficiency and reduce overall project costs. With IPD, the owner, tenant, building operator, general contractor (GC) and trade partners (major subcontractors) are all integral to the design process. The large IPD team for the Knight Cancer Research Building co-located into shared office space, which fostered collaboration and teamwork, and allowed communication to flow more quickly and freely than a traditional design-bid-build project.

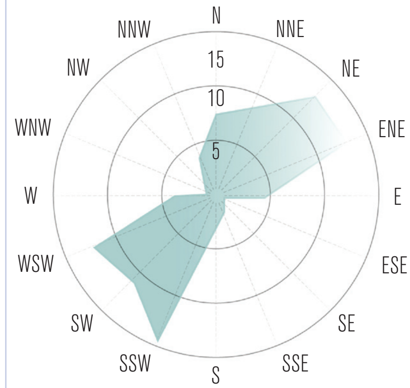
Cost-effectiveness during the design process was achieved by having representatives from the Knight Cancer Institute involved in discipline-specific functional team meetings. The design team was able to respond to their needs and requirements immediately during the design process rather than waiting for milestone review periods, which reduced the amount of redesign effort required.

One specific way this helped reduce project costs was by evaluating the laboratory compressed air system. The project requirements initially included a compressed air system to all lab spaces; however, the lab managers were able to recognize the limited need for compressed air based on the types of research they were planning. By scaling the system to local compressors only where needed, the project was able to reduce construction costs by over $100,000 and saved the design team from having to detail a system that was not needed.

Several strategies proved successful on the project with respect to controlling construction costs. The GC and trade partners were brought onboard when the project was still in schematic design and were able to provide real-time feedback on construction costs and constructability of proposed systems. This proved to be very valuable when evaluating cost reduction options. A value engineering log was maintained to capture both cost saving ideas as well as risks that had potential to increase project costs.

To evaluate cost-effectiveness of proposed energy-efficiency measures, payback analyses of each measure were performed using first-cost data from the contracting team, operating costs from the owner and energy impact and cost from the design team.

FIGURE 4 Wind direction distribution percentage.



Environmental Impact

The environmental impact of the project was discussed and evaluated throughout the design phase. Typically when building energy use is evaluated, it is based on site energy—the energy used at the building site. This provides a good apples-to-apples comparison of energy use in buildings regardless of where that energy comes from. For this project, source energy was also evaluated. Source energy is the energy required to generate and distribute the energy required at the building.

For natural gas, site and source energy uses are nearly identical because the combustion process occurs at the building site. Electrical energy, however, is generated remotely and experiences significant losses in efficiency through its generation and distribution before being used at the building. This building is expected to generate 36% less carbon than baseline when looking at site energy, and 29% less carbon than baseline when looking at source energy.

It is understood that the environmental impact of the building's operation will change over time due to how electrical energy is sourced. Power to the site is provided by Portland General Electric, which currently uses coal to generate 34% of the electricity it produces. Oregon Senate Bill 1547 requires electric companies serving customers in Oregon to eliminate coal-fired resources from their electricity supply by 2030 and to use more renewable resources for energy production. This "greening of the grid" will result in the building having a lower environmental impact over time.

Even though the energy use will not change, the carbon produced in generating that same energy will decrease. It also emphasizes the environmental benefits of using electrical sources over natural gas to meet heating demands. The heat recovery chiller used in this project is a good example of an effective way to shift to a non-carbon-based heating source.

PHOTO 2 Mechanical room.

In addition to carbon emissions, water reduction was an important environmental objective. Low-flow fixtures, including 1.28 gallons/flush (4.85 L/flush) toilets and 0.125 gallons/flush (0.473 L/flush) urinals reduce the potable water use by 300,000 gallons (1.1 million L) annually compared to standard flow fixtures.

The project also uses a rainwater reclamation system, which takes advantage of Portland's abundant water supply and uses rainwater collected on site to flush toilets and urinals. Rainwater falling on the roof is filtered and collected in a large cistern located in the basement. The water is filtered again, sterilized via ultraviolet treatment and distributed to flush fixtures in the building. It is estimated that rainwater will reduce potable water use by over 400,000 gallons (1.5 million L) annually.

Conclusion

The success of this project stems from the cohesive team environment and shared focus on one unifying goal. By using a "Big Room" co-location strategy, open communication, and collaborative knowledge sharing, engineers and designers were able to select and vet systems in real time, designing a landmark LEED Platinum laboratory building to support cancer researchers. Ultimately, the goals of this project were realized because of the team's dedication to the larger mission, and the recognition that they were one component to a broader goal: to detect cancer earlier, improve the health and morale of patients, and in the words of the building's namesake, Phil Knight, "to end cancer as we know it." ■

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