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Oregon Sustainability Center: Weighing Approaches to Net Zero

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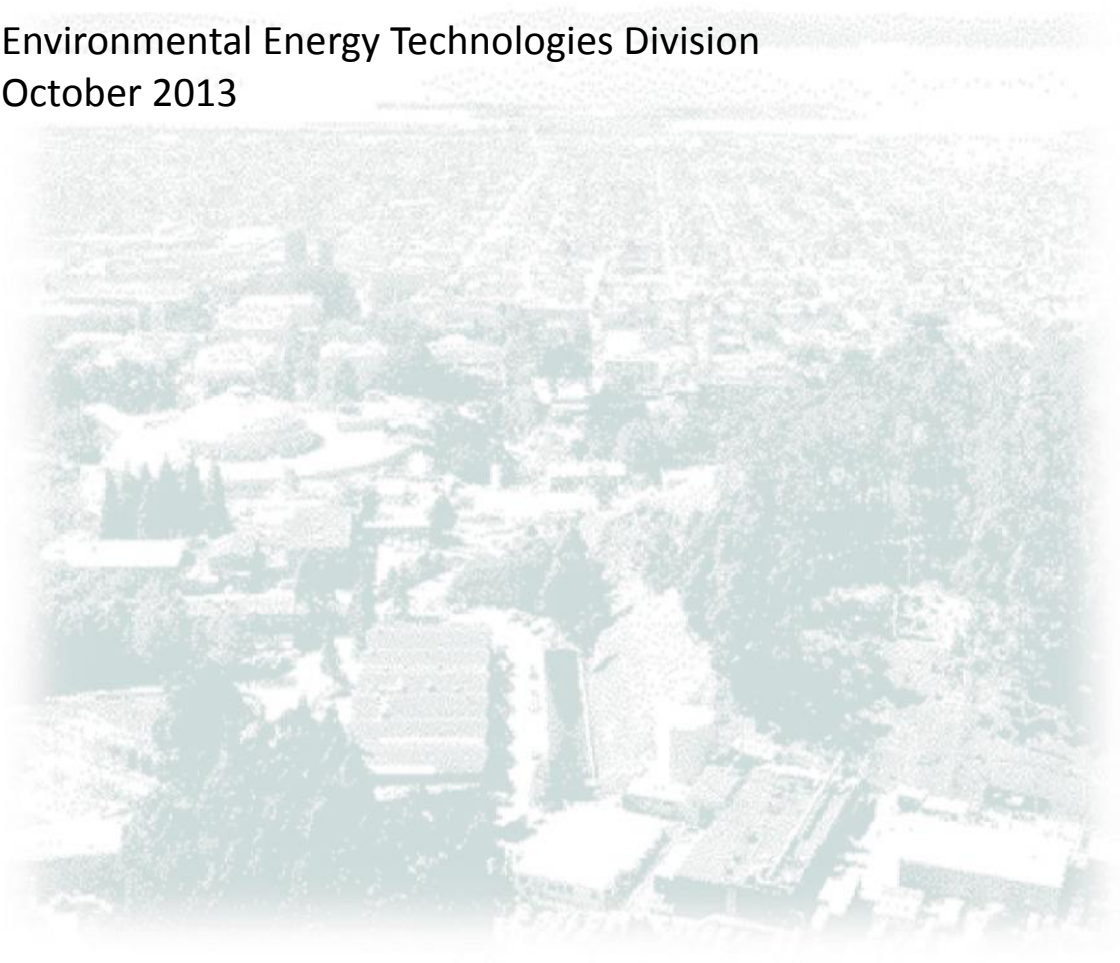

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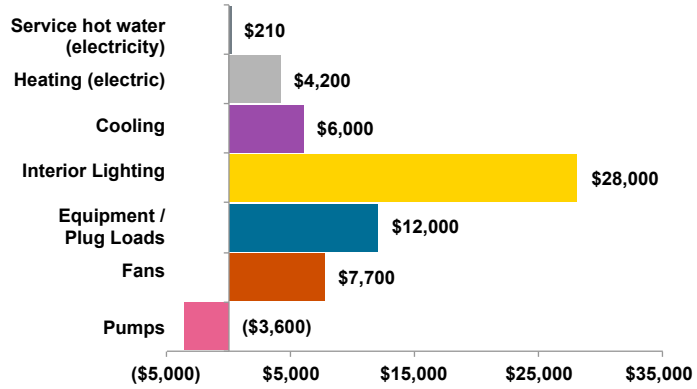
Oregon Sustainability Center: Weighing Approaches to Net Zero

Overview

The Oregon Sustainability Center (OSC) was to represent a unique public/private partnership between the city of Portland, Oregon, state government, higher education, non-profit organizations, and the business community. A unique group of stakeholders partnered with the U.S. Department of Energy (DOE) technical expert team (TET) to collaboratively identify, analyze, and evaluate solutions to enable the OSC to become a high-performance sustainability landmark in downtown Portland. The goal was to build a new, low-energy mixed-use urban high-rise that consumes at least 50 percent less energy than requirements set by Energy Standard 90.1-2007 of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), and the Illuminating Engineering Society of America (IESNA) as part of DOE's Commercial Building Partnerships (CBP) program.[1]

In addition, the building design was to incorporate renewable energy sources that would account for the remaining energy consumption, resulting in a net zero building. The challenge for the CBP DOE technical team was to evaluate factors of risk and components of resiliency in the current net zero energy design and analyze that design to see if the same high performance could be achieved by alternative measures at lower costs. In addition, the team was to use a "lens of scalability" to assess whether or not the strategies could be applied to more projects. However, a key component of the required project funding did not pass, and therefore this innovative building design was discontinued while it was in the design development stage.

Expected Energy Cost Reductions



A view of the Oregon Sustainability Center from the northwest.

GBD Architects and SERA Architects

Project Type	Mixed-Use: Office and Retail, New Construction
Climate Zone	ASHRAE Zone 4C, Marine
Ownership	Private
Barriers Addressed	• Depth of floor plate required maximization of passive strategies • Effectively utilizing daylight by optimizing façade design per orientation • Analysis identifying additional challenges to implementing perceived high-performance systems
Square Footage of Project	~131,000
Expected Energy Savings (vs. ASHRAE 90.1-2007)	50.6%
Expected Energy Savings	~643,500 kilowatt-hours (kWh)/ year of electricity
Expected Cost Impact (vs. ASHRAE 90.1-2007 baseline)[2]	~$54,510/year savings
Actual Cost Reductions	To be determined
Project Simple Payback	Full energy-efficiency measures (EEM) set was >30 years
Expected Carbon Dioxide Emissions Avoided[3]	~250 metric tons of CO_2e per year
Project Completion Date	To be determined

1. The Commercial Building Partnerships (CBP) Program is a public/private, cost-shared initiative that demonstrates cost-effective, replicable ways to achieve dramatic energy savings in commercial buildings
2. Cost reductions were calculated using $0.0845/kilowatt-hour (U.S. Energy Information Administration [EIA] commercial rate average for Oregon in May2013).
3. 642,591 lbs of carbon dioxide equivalents [CO2e] per year (assuming 863.36 lbs/megawatt-hours [MWh] for the eGrid Subregion NWPP [eGrid 2010])

This case study provides insight into the analysis approach, outcomes, decision criteria, and lessons learned through the course of the design process for this net zero energy design project. The OSC was to be a 131,000+ square foot (sf) urban, mixed-use high-rise to be located on the eastern edge of the Portland State University (PSU) campus. It was proposed as the anchor for Portland's downtown pilot EcoDistrict. The plan was to bring together sustainability-driven businesses and non-profits, university-level education and research, energy policy and planning, workforce development, and public agencies—all under one roof. The neighborhood development strategy aimed to integrate high-performance buildings with city infrastructure and to reduce greenhouse gas emissions, energy use, and water use.

The OSC was designed with a goal to become one of the first high-rises in the world to achieve the Living Building Challenge™ certification and to showcase green building technologies and innovations. Taking the target of >50 percent energy savings compared to ASHRAE 90.1 to another level, the project was designed to produce 100 percent of its energy on site, through self-sustaining energy-generation and distribution systems. To build an infrastructure for success, efforts were being put in place to achieve and exceed the aggressive design target by (a) monitoring the performance daily, (b) engaging and educating the occupants, and (c) allowing sufficient flexibility for revision as innovations in sustainable design and technology continued to emerge. Once in operation, maintaining and improving energy performance was to be an important long-term goal.

The energy efficiency measures (EEMs) proposed for the OSC consisted of a mix of cutting-edge and/or emerging technologies and commercially available, mature technologies. In addition there was a strong interest in incorporating a high percentage of market-ready options, which could support replication by other projects. The OSC was proposed as an all-electric building, which allows for tighter integration with on-site renewable energy production. In general, the goals for energy efficiency for the project were aggressive, and would be considered state-of-the-art in today's commercial construction sector.

To determine the project's anticipated costs and savings for the EEMs, life-cycle cost analyses were performed at different stages in the process. The life-cycle cost is the total cost of owning, operating, and maintaining the building system(s) over a given period, with all costs discounted to the current year to reflect the time-value of money and the discount rate of the institution funding the project. When considering measures for implementation, life-cycle cost can be a valuable tool to determine if a combination of the capital and operating costs of certain measures will yield a net benefit during the life of the building. Offset utility bills, savings and adjustments in operations and maintenance, and increased environmental attributes are examples of data evaluated in addition to first costs. This type of analysis provides understanding of the impact of decision making during the design of a system projected to last a minimum of 20 to 30 years. After construction is completed, additional work would be required to validate the performance of a project's EEMs.

Although the project did not move forward into construction, a number of valuable lessons learned during this integrated design process are important to share with industry.

Decision Criteria

The Oregon Sustainability Center was conceived by the project team as a future showcase of sustainable innovation in Oregon. The primary decision criteria were the ambitious goals of achieving net zero energy, water, and carbon, and the pursuit of the Living Building Challenge certification. The intent was to use the building design strategies and systems as a showcase and case study for education and research, and to demonstrate that high-performance was also possible from a constructability and operational standpoint.

The larger project team, which also included the owner, participated in a comprehensive integrative design process that included all the relevant stakeholders, including the CBP TETteam. The design team developed a comprehensive list of systems and design solutions that were evaluated and adapted based on a number of performance parameters and utilized a number of tools and resources throughout the integrative process. The CBP team's decision criteria added another layer to the OSC project teams' decision criteria for the net zero design. For measures to be considered and analyzed, they were initially evaluated in terms of risk reduction, resiliency, and applicability to other projects. These criteria are a part of a broader set of decision criteria that should be considered by net zero energy project teams in the future.

Economic

The economic criteria considered for the CBP team's efforts focused on first cost, payback period, and life-cycle cost analysis (LCCA) over a thirty-year period. For the LCCA analysis to be representational, a series of rates were incorporated. The capital costs for the project construction budget were evaluated at a discount rate of 5 percent, with 8 percent for basic contract responsibilities, and a 1.8 percent contractor overhead. In addition, a design contingency of 2.5 percent during construction was also included, and the electrical escalation rates were set at 2 percent per annum.

Operational

The building was designed as a privately owned and operated property with a long ownership period being targeted for the owner. Therefore, considerations for maintenance costs and replacement costs were a factor in determining investment strategy. A key assumption was that the annual maintenance work would be performed in-house, while repair and replacement work would be conducted by service contracts.

At different stages of the CBP team's process, different system and strategy criteria were used as a filter to inform efficiency measure recommendations. A key set of criteria that served as a filter to evaluate the advantages and disadvantages of ground-source heat pump open- and closed-loop systems, accounting for operational issues as well:

- Flow rates of wells, initially and over time
- Testing frequency and types, including acidity and iron content
- Potential for aquifer cross contamination
- Microbial growth and its potential impact on equipment life
- Required flow dependent on load and loop length
- Quality control of the installation and its influence on performance
- Heat fluid transfer choices and potential rate of corrosion

Additional criteria filters for evaluation of different systems types, such as variable air volume (VAV) and VAV with heat recovery and radiant systems were utilized throughout the process.

Design

The OSC project was envisioned as a living laboratory of high-performance building technologies and best practices. Through partnerships with many research institutions, such as the Oregon University System and the DOE's CBP program, this project was also envisioned to be a catalyst for research in sustainability, innovation, and economic opportunities for the green workforce. Some of the key design criteria evaluated during the integrative design process included:

- The local climate and its influence on passive, hybrid, and different types of HVAC systems considered.
- Thermal comfort and adaptive thermal comfort for natural ventilation
- Efficiency measures addressing both energy and water
- Efficiency measures providing a visible face to energy efficiency
- Excellence in performance and environmental innovation in the built environment

Policy

- The Oregon Sustainability Center was originally planned as the Oregon headquarters of the International Living Future Institute and various other non-profit organizations. What made this proposed building unique was that the OSC was targeting achievement of the highest building sustainability rating systems currently recognized. The main policies governing the project design were:

- Leadership in Energy and Environmental Design (LEED) Platinum Certification
- Living Building Challenge Certification, including Net Zero Energy
- Guidelines for the Portland EcoDistrict
- Requirements for utility rebates
- Identifying ways to engage policy makers directly in the project

Energy Efficiency Measures Snapshot

Table 2 shows the CBP team's alternative energy-efficiency measure (EEM) sets that were recommended for this project based on risk, resiliency, and applicability to other projects. The EEM sets are displayed by category (lighting, envelope, HVAC and plug load), and therefore are not shown in sequential order. In a large percentage of the cases, the EEM set contains more than one energy-efficiency measure, and the set of measures were modeled as a package. The following list provides additional context for Table 2 for the EEMs included:

- Local, state, and federal rebates, which are generous for buildings of this type in Oregon, were not included in the EEM cost calculations.
- The cost of electricity is on average assumed to be $0.0845/kilowatt-hour.
- Though dimming fixtures could have been used for this project, it was assumed that the lights would only be dimmed when daylight was sufficient. Lights would not be dimmed for any other purpose (such as demand response) nor were they assumed to be dimmed on a regular basis as a means to save additional energy, which is a common practice among facility engineers who have this technology.
- EEM 4 contains a heat recovery loop aimed at recovering energy during simultaneous heating and cooling. However, this feature could not be modeled in EnergyPlus, and therefore the potential energy savings are not factored into the values shown. An acceptable "modeling workaround" was not identified.
- EEM 5 and EEM 6 sets analyze an open-loop ground-source system in which the ground water is used directly to cool a radiant ceiling slab installation. The proposed scheme does not include any compressor-based cooling and, as such, the cooling energy and associated heat rejection energy uses are zero.
- The EEMs are alternatives to the current design that consider a number of other factors, which, as the analysis shows, did not provide simple payback totals in acceptable ranges.

Energy Efficiency Measures

	For This Project	Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost (Initial)	Simple Payback	Cost of Conserved Energy (CCE)[4]
	Yes/No	Yes/No	kWh/yr	$/yr	$	yrs	$
LIGHTING (INLCUDE % SAVINGS OVERALL FOR LIGHTING EEMs AT WHOLE BLDG LEVEL)							
EEM Set 2 — Lighting							
Improved light-emitting diode (LED) lighting: office lighting power density (LPD) from 1.1 watts per square foot (W/ft^2) to 0.35 W/ft^2, retail from 1.7 W/ft^2 to 1 W/ft^2, occupancy sensors throughout facility	Yes	Yes	341,666	$28,871	$644,934	22	$0.17
Daylighting Sensors: Daylight dimming system for first 20′ of building perimeter footprint	Yes	Yes					
ENVELOPE (INLCUDE % SAVINGS OVERALL FOR ENVELOPE EEMs AT WHOLE BLDG LEVEL)							
EEM Set 3 — Envelope							
Improved: Walls R-15.6 to R25; Roof R-20.8 to R-38.5	Yes	Yes	69,731	$5,892	$1,861,479	>30	$1.90
Improved Glazing: Glazing assembly U-value from 0.4 to 0.24, Solar Heat Gain Coefficient (SHGC) 0.4, maintain overall building 0.35 Window-to-Wall Ratio (WWR)	Yes	Yes					
Optimized South Façade: Lightshelf and shading system optimized, daylight and view windows split; Higher visible light transmittance for daylight portion of glazing	Yes	Yes					
EEM Set 8 — Envelope							
Improved Envelope: Deep shading fins on the east	Yes	Yes	-751	($64)	$141,993	NA	($13.42)
EEM Set 10 — Envelope Controls							
Automated Natural Ventilation: Automated façade motors to augment manually operated windows during daytime and during night flush events	Yes	Yes	55,145	$4,659	$18,932	4	$0.02

4. The cost savings were based on a utility rate of $0.0845/kWh. The cost of conserved energy (CCE) was evaluated with 5% discount rate for 25 years

Energy Efficiency Measures for Selected GSA Sites

	For This Project	Consider for Future Projects	Expected Annual Savings		Expected Improvement Cost (Initial)	Simple Payback	Cost of Conserved Energy (CCE)[4]
	Yes/No	Yes/No	kWh/yr	$/yr	$	yrs	$
HVAC (INLCUDE % SAVINGS OVERALL FOR HVAC EEMs AT WHOLE BLDG LEVEL)							
EEM Set 4 — HVAC							
Dedicated Outdoor Air System (DOAS) w/Heat Recovery: 100% Outdoor Air (OA) air handlers with 80% sensible heat recovery devices, increased ventilation rates to 0.5 cubic feet per minute per square foot (cfm/ft^2) in occupied areas, Variable Fan Drive (VFD) for fan motors	Yes	Yes	48,448	$4,094	$375,871	>30	$0.55
Integrated Radiant Slab Ceiling: 4-pipe system with 5/8″ PEX tubing, 6″ o.c., manifolds with powered valves provide zoning and flow control, variable speed secondary circuit provides pump power	Yes	Yes					
EEM Set 5 — HVAC							
Open-Loop Ground Source Aquifer Free Cooling: Nine-hundred foot well with three staged 3.6-hp constant-speed submersible pumps	Yes	Yes	-16,732	($1,414)	$832,995	NA	($3.53)
EEM Set 6 — HVAC							
Water-source heat-pump on Open-Loop Circuit: Eleven 180 kBtu/hr high-efficiency (Coefficient of Performance: COP-4.2) water-source heat pumps, staged in parallel	Yes	Yes	38,918	$3,289	$124,413	>30	$0.23
EEM Set 9 — HVAC							
Central Plant Modifications: Open ground loop not installed, 11 180 kBtu/hr high-efficiency water-source heat pumps used now for both heating and cooling.	Yes	Yes	-53,379	($4,510)	$364,927	NA	($0.49)
Closed-Loop Ground Source Heat Pump: 35,000 ft of 1″ PEX tubing, 80 Ton Cooling Tower, water-side economizer controls, plate and frame heat exchanger connecting ground-source loop to cooling tower.	Yes	Yes					
PLUG LOADS (INLCUDE % SAVINGS OVERALL FOR PLUG LOAD EEMs AT WHOLE BLDG LEVEL)							
EEM Set 7 — Internal Loads							
Reduced Plug Loads: plug loads reduced from design load of 1.68 W/ft^2 to 1.0 W/ft^2 due to equipment choices that were incorporated into the building design	Yes	Yes	157,587	$13,316	$0	0	0

Energy Use Intensity by End Use

Overview

Two energy models were created to compare the proposed low-energy design with a baseline building defined by ASHRAE 90.1-2007. EnergyPlus was used to simulate the two whole-building energy models, utilizing the software's capabilities to model natural ventilation, building controls, a geothermal loop, and low-energy HVAC systems.

The energy modeling analysis showed that it is possible to achieve the 50 percent energy savings target through various combinations of EEMs. No single technology is capable of achieving the desired level of savings, so the decision criteria assisted in guiding the project team to the appropriate set of EEMs as the project progressed. All told, these measures resulted in energy costs reduced by 50.6 percent below ASHRAE 90.1-2007.

The envelope included the use of true R-25 walls, an R-38 roof, and triple-pane windows with argon fill and two low-e coats, achieving an overall window assembly U-value of 0.24 and a solar heat gain coefficient (SHGC) value of 0.4. Four-foot exterior, horizontal shades were included on the south façade, and these could also provide an energy harvesting surface where photovoltaics (PVs) are incorporated. Deep 5.5-foot vertical fins are used on the building's east façade to shade that area from morning solar penetration.

The recommended lighting efficiency improvements included the use of high-efficacy light-emitting diode (LED) lighting, with daylight harvesting and dimming ballasts throughout the regularly occupied zones, which reduced the installed power density by almost 70 percent.[5] The LED ballasts are dimmable over a wide range, meaning that daylight dimming hardware could be integrated into the banks of ballasts at the building perimeter (20 feet from the interior) to allow for programming of individual fixtures, to provide the greatest flexibility for the occupants. In addition to their use in regularly occupied spaces, occupancy sensors and high-efficiency fluorescent lights were also used in storage and ancillary support spaces.

An innovative approach towards the management of internal loads, binding to both owner and tenants, was to be instituted as office policy. The approach was to involve a certain percentage of the employees that would be identified as mobile employees, given laptops, and provided community desk environments optimized for laptop working. The approach would have reduced the number of computer monitors, and when combined with the specification for ENERGY STAR equipment, it would have reduced the plug load power density from 1.69 watts per square foot (W/ft^2) to 1.0 W/ft^2. A commitment of strict adherence to this office policy would have allowed the design team to take an energy-efficiency credit for reducing plug loads which, even at the reduced level, were shown to be a significant energy consumer for the building.

The recommended low-energy HVAC design measures incorporated a number of different components and strategies. Key components include the regularly occupied office and retail spaces being served by an integral radiant slab system, with high-efficiency Dedicated Outside Air (DOA) handlers that include an efficient sensible-only air-to-air heat exchanger. The recommended central plant was to consist of packaged high-efficiency geothermal heat pumps, utilizing a closed-loop vertical borefield and variable-speed primary-only pumping with local variable-speed recirculation injection pumping for temperature control. The central plant would realize a higher efficiency, as the radiant floor water temperatures would not require the compressor lift needed for a conventional chiller system.

Model 1: Code Baseline

The ASHRAE 90.1-2007 baseline building model reflected standards enshrined in the building performance rating method. The wall (R-13.0 + R-7.5 continuous insulation [c.i.]), roof (R-19.0), and window (U = 0.40; SHGC = 0.40 All) performance values were as-required for the Portland, Oregon, climate (Climate Zone 4C for Multnomah County). To align with the project vision for a net zero energy building, the energy-efficient design was for an all-electric building with solar photovoltaic panels on different surfaces of the building. The approach to achieve net zero energy on an annual basis would have involved energy being taken from the grid when solar energy is scarce and being returned to the grid when solar energy is abundant on site. Due to the building's floor area, code required the baseline building HVAC system to be a VAV system with local parallel fan-powered boxes and electric resistance heat, with a chilled water central plant and axial cooling tower with two-speed fans.

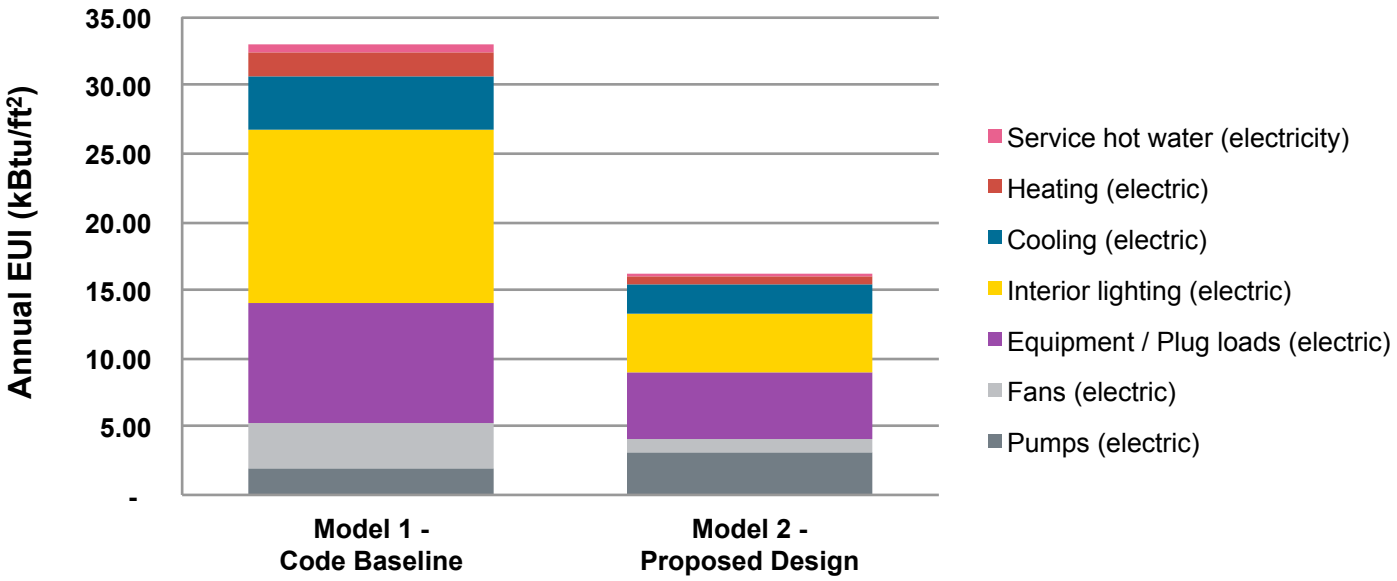
Ancillary needs, such as IT equipment cooling and electrical room spot cooling, are accomplished with local split DX cooling. An airside economizer is also required in the baseline DX system, to take advantage of the many hours of free cooling available in the Oregon climate. The design loads for these spaces were not known at the time, and the loads for these spaces were modeled at 1.5 W/ft^2, which is certainly an underestimate of the actual power intensity of these spaces.

Model 2: Proposed Design

The proposed design energy model includes the set of EEMs proposed in the Energy Efficiency Measures table. The energy model was utilized throughout the process to evaluate where the alternative proposed design stood in terms of its energy performance targets (see the Energy Efficiency Measures Snapshot section for notes on some of the energy modeling challenges).

5. The lighting power density for the LED scenario is 0.35 W/ft^2 vs. 1.1 W/ft^2 for the ASHRAE baseline in the office areas.

Comparing the Energy Use Intensity of the Code Baseline and the Proposed Design Model



Expected Annual Energy Use and Percent Savings by End Use

End Use Category	Model 1 – Pre-retrofit Design	Model 2 – Code Design	
	Annual EUI (kBtu/ft²)	Annual EUI (kBtu/ft²)	Percent Savings over 90.1-2007
Service hot water (electricity)	0.43	0.3	16%
Heating (electric)	1.86	0.6	70%
Cooling (electric)	3.85	1.99	48%
Interior lighting (electric)	12.79	4.3	66%
Equipment / Plug loads (electric)	8.67	4.98	43%
Fans (electric)	3.38	1.01	70%
Pumps (electric)	1.96	3.06	-56%
Total	**32.94**	**16.25**	**~50.6**

Lessons Learned

"The entire Oregon Sustainability Center design process was a demonstration of the collaborative spirit of our state. Bringing in the CBP team was a natural extension of that — leveraging the best available resources to pursue a bold, shared vision. While the building wasn't constructed, the process continues to provide lessons for future projects."

— Johanna Brickman

Director of Collaborative Innovation,
Oregon BEST, OSC project team member leading research efforts

Even though this project is not proceeding past the design stage, a number of valuable lessons were captured by the CBP project team. These lessons, summarized below, are applicable to similar office/ mixed-use projects that might pursue deep energy-reduction or Living Building Challenge goals. They include not only the design and systems phase summary but a comparative vision into post-occupancy, operations, and investment strategies.

The Challenges of High-Performance Systems and Strategies

The building design was intended to use best-in-class technologies from the outset, and had very aggressive energy-efficiency goals. Ambitions to achieve deep energy savings often come with many challenges, and the following three examples demonstrate how those challenges can lead to trade-offs and emphasize the importance of an integrative approach.

Digging Deeper:

The lowest-energy option may not be the preferred solution. At one stage of the design, the entire cooling system was intended to utilize a groundwater aquifer, which would have eliminated cooling compressor energy altogether. However, this aquifer cooling system would have required drilling to depths in excess of 600 feet to avoid corrosive iron-eating bacteria that lived at shallower depths. This option proved to not be viable due to the capital intensity of the system and uncertainty about the future development of the bacteria in the soil. Switching to a closed-loop system proved to be not as energy-efficient; though avoiding these potential hazards outweighed the energy penalty.

The Ripple Effect:

Numerous factors influence the selection of the HVAC system type, and additional factors can come into play when certain parameters, such as a specific floor-to-floor height, are turned into requirements. A radiant and dedicated outdoor air system (DOAS) can typically be designed for lower floor-to-floor heights than conventional systems, so normally the energy savings can be further leveraged by capturing the first-cost savings associated with constructing a lower floor-to-floor height. However, since the floor-to-floor height was set and not adjustable, this cost offset could not be included as part of the economic case for its implementation.

Competing Against Free Cooling:

The Oregon climate is ideally suited for systems that include an airside economizing capability. During the process, it was discovered that one drawback of a DOAS and radiant floor system was the loss of "free cooling" that would be provided by a system with an airside economizer. Since the DOAS restricts the amount of outside air intake to lower supply levels (intake reduced from 1 cubic foot per minute [cfm]/ft^2 to 0.2 cfm/ft^2), the potential to use this this free cooling would be drastically reduced. To overcome this difference, the façade required 1,400 ft^2 of operable windows. Of these operable windows, 25 percent were to be automated and tied to the building management system (BMS) to open and close automatically when conditions were favorable. A night-purge sequence programmed into the BMS would open the windows in the evening, which would be coupled with return fans drawing air through the building. The natural ventilation system resulted in a 20 percent decrease in annual cooling energy and a similar reduction in fan energy. Therefore, the DOAS and radiant HVAC system design did achieve higher levels of performance than a system with an airside economizer, along with other benefits, but the team had to work and think creatively to get that result.

Energy Modeling: Parametric Simulations and Integrating Results

Better energy modeling processes are needed to achieve low-energy targets and optimized cost savings. Since the project team had a computer programmer on staff, the team was able to experiment with a few different approaches. The EnergyPlus output files, which are very flexible and easy-to-process, were reformatted, allowing the team to make strides in automatically generating the modeling results in a format that was more palatable for the cost-estimating team. Many team members found this to be a far better process, and tools like EnergyPlus are well-positioned to offer this capability. This is an example of the type of features that need to be incorporated into simulation tools.

Another energy modeling approach that would have greatly helped the CBP team to identify conventional technologies for

a more cost-efficient design would have been to use parametric modeling with ties to a knowledge database. In this approach, information about the building shape, construction materials, and systems could be extracted from EnergyPlus and automatically translated into a format suitable for the life-cycle cost estimation team to conduct their work. All of the incremental changes to the EnergyPlus simulation could then be done programmatically, and after each simulation, the results could be analyzed by a computer program that reviews project inputs and the resulting costs. An automated method to batch EnergyPlus simulation runs and effectively process the results for different team members could streamline approaches to cost estimating and other tasks, increasing the availability of different types of information at the appropriate time.

Beyond Design Energy: Engaging Occupants

Occupants remain the key to realizing and maintaining energy savings over time. However there is still not sufficient data to model this effect without a higher level of uncertainty. As the efficiency in building design and building systems increases, the need to focus on the energy consumption of plug loads and occupants becomes more apparent. This observation is supported by numerous industry research studies that have demonstrated that between 30 to 50 percent of potential energy savings are tied to employee or tenant use of the office environment. If occupant usage patterns vary significantly from what is assumed in the energy model, then the annual energy consumption level can vary significantly from design to actual building operations. Therefore a number of pre- and post-occupancy engagement efforts were planned, aimed at extending occupant awareness and education to help improve and maintain the energy-reduction goals during occupancy.

Review the Full Cost Picture: Overall Lifecycle Net Present Value (NPV) and Annual Maintenance and Operations (M&O) Savings

Based on the analysis of initial costs, energy savings, and annual maintenance, all of the EEMs achieve significant annual electricity savings; however, the level of cost to incorporate the different EEM sets into the proposed building indicated that in a number of cases there would not be a payback within 30 years, with the exception of EEM 2—"Improved Lighting and Daylighting Sensors", EEM 4 – "Internal Loads", and EEM 10 – "Envelope Controls". There are two key takeaways from this result: (1) the cost estimates of certain types of low-energy systems are still extremely high, possibly as a result of the cost of risk for unfamiliar and/or perceived-to-be emerging systems, and (2) for net zero energy projects it can be beneficial to carry cost considerations further into maintenance and operations.

The geothermal open-versus-closed-loop comparison that was discussed earlier provides a good example. In addition to reviewing overall payback, it is also critical to review annual M&O savings. Often, M&O budgets are strained, and although an EEM may not necessarily yield significant overall NPV, M&O annual savings may be significant, and thus the EEM may be worth further consideration. In such cases, it may be valuable to review other capital investment strategies such as fundraising, loans, or program changes, so that annual M&O savings may be realized.

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