NET ZERO FELLOWSHIP RESEARCH

CARBON CROSSROADS: AN ANALYSIS OF OPERATIONAL AND EMBODIED CARBON IN MULTIFAMILY HOUSING

FELLOW: HANNAH RUSNAC, HOLST

Hannah Rusnac analyzed the operational, embodied, and whole life carbon of eight multifamily buildings in the Pacific Northwest. Her research will inform the design and whole life carbon emission of future multifamily construction.

GOALS

- Provide public operational and embodied carbon data, especially for low- and mid-rise wood frame multifamily construction in Oregon.
- Determine the predicted life-span balance between operational carbon and embodied carbon for eight multifamily projects in Oregon.

APPROACH

- This study looked at five projects located in Portland, Oregon, and three in Boise, Idaho. This includes a mix of site-built wood frame, wood frame modular construction and site-built wood frame over concrete podium construction, as well as both affordable and market-rate projects.
- Operational carbon emissions were calculated based on the electricity and natural gas usage data. Where the usage data was unavailable due to permissions or construction timing, operational carbon emissions were calculated based on estimated energy usage data from an energy model of the project.
- Embodied carbon emissions were calculated using the software program Tally, which generates a whole building life cycle assessment based on a 3D digital building model.

FINDINGS

- At the end of a building's life, embodied carbon is predicted to be 25% to 45% of a building's whole life carbon, with a median of 32%.
- Operational carbon ranged from 26.6 kg to 55.2 kg CO_2 eq/m^2/yr across a range of modeled and actual data.
- Initial embodied carbon ranged from 42.8 kg to 172.2 kg CO_2 eq/m^2. The life cycle embodied carbon was between 167.1 kg and 257.3 kg CO_2 eq/m^2.
- Total whole life carbon was between 582 kg and 1,542 kg CO_2 eq/m^2.
- In all-electric buildings, embodied carbon is predicted to be a higher percentage of the whole life carbon due to grid decarbonization assumptions.
- In light wood frame buildings, without concrete podiums, operational carbon quickly surpassed embodied carbon.

VIEW THE RESEARCH

Scan the QR code to access the full research report published in 2023, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO FELLOWSHIP RESEARCH

A PROTOTYPE FOR AFFORDABLE, RESILIENT, LOW-ENERGY COTTAGE CLUSTER HOUSING

FELLOW: JESSY LEDESMA, HOMEWORK DEVELOPMENT

Jessy Ledesma studied opportunities to reduce energy use and increase resilience in affordable housing. She analyzed the impact of clustering units, using mass plywood panels, centralizing mechanical and hot water systems, and optimizing the development scale for solar microgrids. The analysis focused on the Milwaukie Courtyard Housing Project as a prototype.

GOALS

- Increase industry knowledge of net-zero multifamily construction in Oregon by analyzing the use of mass plywood panels coupled with high-performance passive and active heating systems and solar microgrids.
- Prototype workforce housing at a cottage cluster, infill scale using a unique combination of strategies that help meet community energy, affordability and resiliency goals.

APPROACH

The research was conducted in partnership with the University of Oregon Energy Studies in Buildings Laboratory. It included an energy model of a prototypical mass plywood panelized single-family house with a slab-on-grade foundation and an all-electric monobloc heat pump system configured individually for each unit or as a district strategy.

Additional resources included a physical mockup of a frameless mass plywood panel high-performance window that involved infiltration testing and thermal imaging, as well as a solar analysis of courtyard cluster housing that considered ways to preserve the existing tree canopy on three potential sites. Finally, a cost and affordability analysis examined the financial feasibility of a solar cluster microgrid.

FINDINGS

- The combination of mass plywood panels, innovative window assembly, community solar electric production, and centralized hydronic conditioning and hot water systems greatly increases energy efficiency compared to a more typical construction strategy.
- The solar installation provides 62%–66% of energy requirements. A two-story cluster housing site design optimizes the solar-to-energy usage ratio more efficiently than taller (3–4 story) buildings or with individual unit arrays.
- The projected net cost is financially feasible for housing units affordable up to 100% area median income (AMI), but will require additional subsidy for the model delivering units affordable up to 80% AMI.

VIEW THE RESEARCH

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NET ZERO FELLOWSHIP RESEARCH

REMOVING BARRIERS TO NET ZERO COMMERCIAL INDUSTRIAL DEVELOPMENT

FELLOW: JEAN VON BARGEN ROOT, MWA ARCHITECTS

Jean von Bargen Root evaluated current and future climate conditions, assessing how local codes, standards and policies help or hinder net-zero performance in commercial-industrial developments. The study examined the three fastest-growing regions in Oregon where commercial-industrial development has a significant impact on regional energy consumption: Willamette Valley, Rogue Valley and High Desert.

GOALS

- Increase industry knowledge on how to achieve net-zero energy performance within commercial-industrial development in Oregon.
- Identify potential barriers in local building codes, standards and policies.
- Provide a design process framework for net-zero commercial-industrial construction.
- Work with BIPOC individuals and women-owned businesses to expand the reach of the research results.

APPROACH

The research began with a scan of building development ordinances in Willamette Valley, Rogue Valley and High Desert to identify potential barriers. Interviews with public agencies offered insights into development dynamics and in-progress policies and codes. The team linked this research to each region's geology and current and future climate conditions to identify specific net-zero design opportunities.

Based on these findings, a design guide was developed to provide project teams with examples of design and detailing for four typical commercial-industrial building types: mixed-use office, warehouse, pre-engineered metal buildings and unoccupied service buildings. The design guide can serve as a checklist for commercial-industrial projects across Oregon.

FINDINGS

- Commercial-industrial buildings are often left out of net-zero conversations.
- Oregon's climate is changing in every region, and we need to design buildings in anticipation of those changes.
- Oregon has a variety of regional cultural influences. All can find common ground around energy conservation.
- Many policies and regulations exist, or are in development, to address net-zero energy design and climate change. Approaches vary, and many jurisdictions need funding and policy support to reach net-zero energy.

VIEW THE RESEARCH

Scan the QR code to access the full research report and design guide, published in 2022, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO FELLOWSHIP RESEARCH

REACHING NET ZERO IN AFFORDABLE HOUSING

FELLOW: MARK MCKECHNIE, OREGON ARCHITECTURE, INC.

Mark McKechnie investigated the cost drivers associated with net-zero affordable housing in Oregon. He developed resources for developers, designers and construction teams to evaluate energy-efficiency options and rated them according to cost of construction and return on investment. The study focused on housing units at two multifamily projects in Klamath County, Oregon.

GOALS

- Increase industry knowledge of how to achieve net-zero energy in affordable housing projects.
- Inform local housing authorities about funding to pay for energy-efficiency investments.
- Provide information to market-rate builders about energy-saving strategies and their related costs.
- Provide Oregon Housing and Community Services office with options to modify standard rent and utility calculations to allow for more energy-efficient construction.

APPROACH

The analysis included actual energy use data from Victory Commons and Trails View, and the following energy-saving strategies: building orientation, passive design, reduced thermal bridging, enhanced Trombe wall with heat recovery and heat dissipation, daylighting, weather sealing, efficient windows and doors, solar panels, and efficient home appliances.

McKechnie also developed a cost estimation tool to provide quick estimates of traditional and net-zero construction costs, and to evaluate the cost of energy upgrades against the potential energy savings in dollars.

FINDINGS

- Creating a net-zero or nearly net-zero energy shell is possible with the available technology and reasonable costs.
- Achieving net-zero energy at a whole building level is harder to justify from a cost perspective because it requires an investment in solar panels.
- It is possible and cost-effective to offset operational energy costs by investing in more energy-efficient products and systems from the outset.

VIEW THE RESEARCH

Scan the QR code to access the full research report, published in 2021, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO FELLOWSHIP RESEARCH

THE COST OF MULTIFAMILY ENERGY EFFICIENCY IN OREGON

FELLOW: KATY ANDERSON, GLUMAC

Katy Anderson analyzed energy-efficiency strategies and cost estimations for net-zero multifamily new construction, exploring ways to optimize energy savings per dollar invested.

GOALS

- Help design teams better understand how multifamily buildings use energy.
- Improve design team knowledge of design and market factors that impact multifamily project cost, specifically with respect to energy efficiency.
- Develop resources that teams can use during early design to prioritize energy-efficiency measures that will meet project sustainability goals within budget.

APPROACH

The research focused on multifamily new construction in Oregon, with findings most applicable to midrise (4–11 story) projects. Each energy and cost estimate included occupant density and location as variables. The analysis focused on residential floors with interior corridors. Ground floor retail, lobbies and amenity spaces are not included.

Anderson developed a hypothetical building to determine baseline construction costs and baseline energy use. Her analysis of energy savings included variations in the shell, plumbing and HVAC systems. To develop useful energy and price ranges, the research included energy analysis and pricing for three built projects completed within the previous two years.

FINDINGS

- Centralized heat pump water heaters were a clear winner in cost per energy savings for all locations and densities in the study.
- While heat pump water heaters will significantly reduce the site's domestic hot water energy use intensity (EUI) compared to the natural gas condensing boiler baseline, they will have similar utility costs.
- As mechanical cooling becomes a necessity, design teams should consider whether to prioritize mechanical cooling or ventilation heat recovery more highly.
- During design, investments in solar panels should be compared to potential HVAC and envelope upgrades to determine the most cost-effective solution if tradeoffs are necessary.

VIEW THE RESEARCH

Scan the QR code to access the full research report, published in 2021, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO FELLOWSHIP RESEARCH

PASSIVELY BUILDING FOR RESILIENCY

FELLOW: JOEL GOOD, RWDI

Joel Good studied passive design strategies that create resiliency and prepare new buildings for a changing climate. He examined Oregon's future climate conditions and offered a standardized method, as well as future climate files for two different climate zones (Portland and Bend), to assess the resiliency of proposed developments in Oregon.

GOALS

- Create a standardized method to assess the resiliency of proposed developments in Oregon and provide design teams with a method to evaluate resiliency implications.
- Show the value of passive design strategies for resiliency beyond energy savings (e.g., lower maintenance, longer lifespan, improved indoor environment).
- Create future climate weather data files for Portland and Bend for public use with energy modeling software tools.
- Establish guidance for designers to achieve net-zero energy targets through passive design, while also improving community resiliency.

APPROACH

This study involved a close examination of past and future climate conditions in Oregon and raised the question of how the design and development community can prepare for them. The research hypothesized that a kBtu saved by passive design is more valuable than a kBtu saved by mechanical design because it has the added benefit of improved resiliency.

To fully prepare buildings for the future, the research assessed how local future climate conditions may impact the relative efficacy of passive versus active design solutions on the thermal resiliency and passive survivability of a building.

FINDINGS

- Both Portland and Bend will see climate zone shifts with general warming trends.
- These climate shifts demand different design strategies, including cooling-dominated designs, which will require both energy efficiency with passive strategies and onsite renewable power for resilient, low energy use buildings.
- Passive designs are more thermally resilient in simulated power outages during extreme temperatures.

VIEW THE RESEARCH

Scan the QR code to access the full research report, published in 2019, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO SCHOOLS
FROM PROCESS TO IMPACT

FELLOW: DR. IHAB ELZEYADI, UNIVERSITY OF OREGON

Dr. Ihab Elzeyadi developed a national database of exemplary net-zero schools and studied trends, best practices and relevance to Oregon. The work highlights the most successful strategies to inform the design process for future projects.

GOALS

- Understand the impact of net-zero school design on building performance and the environment.
- Understand the impact of net-zero school design on occupants and building operations.
- Determine successful and replicable strategies and design processes for net-zero schools.

APPROACH

The study created a database of 41 verified net-zero schools in the U.S. and assessed them through a combination of data mining, interviews, surveys, analysis and simulations. Deeper analysis focused on seven schools that are most relevant to the Oregon climate. Elzeyadi studied patterns for success to identify best practices.

FINDINGS

- The current state of net-zero energy schools across North America is promising. It is feasible to deliver affordable schools that are comfortable, cost effective and have positive impacts on children and their communities.
- The process of designing, constructing and operating a net-zero school is integrated and requires early planning, coordination and education of partners.
- Best practices and patterns for success in the following six categories are detailed in the report: design process, design strategies, site performance, building performance, envelope performance and indoor environmental quality/occupant performance.

VIEW THE RESEARCH

Scan the QR code to access the full research report, published in 2020, or visit **www.energytrust.org/net-zero-fellowship**.

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NET ZERO FELLOWSHIP RESEARCH

APPROACHING NET ZERO FOR TODAY'S BUILDINGS

FELLOW: SHILPA SURANA, BRIGHTWORKS

Shilpa Surana evaluated strategies for achieving net-zero energy based on systems that are technically and economically feasible today. Her research focused on midrise multifamily and low-to-midrise office buildings with a case study for each building type.

GOALS

- Identify the most cost-effective design solutions to approach net-zero energy use in midrise multifamily buildings and low-to-midrise office buildings.
- Introduce net-zero strategies for common building types that are not yet typically net zero.

APPROACH

To understand operational performance, the research focused on two existing building case studies, the Vestas Headquarters and Beech Street Apartments, which were both designed for high performance and completed within the previous five years. Surana then evaluated strategies to achieve net-zero energy performance, including building envelope, shading, daylight/lighting and HVAC.

The pro forma analysis included operational energy savings, evaluated cost and overall economic feasibility. The assessment relied on the direct cost of construction materials and labor, including standard markups, and assumes a competitive bid process.

FINDINGS

- For both case studies, there was a significant gap between projected energy use and actual use, likely due to the fact that energy models do not effectively predict how people will use a building.
- Early energy analysis must be planned into the typical design process to support cost-effective design solutions.
- Net-zero technologies are commercially available, but market conditions limit them from widespread adoption.
- Current pricing makes constructing net-zero buildings challenging. New financing options can make a difference.

VIEW THE RESEARCH

Scan the QR code to access the full research report, published in 2018, or visit **www.energytrust.org/net-zero-fellowship**.

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