Hawai‘i Natural Energy Institute Research Highlights

Grid Integration & Energy Efficiency

Energy Efficient Home Design: Department of Hawaiian Home Lands

OBJECTIVE AND SIGNIFICANCE: The objective of this collaboration between the School of Architecture's Environmental Research and Design Lab (ERDL) and the Hawai‘i Natural Energy Institute (HNEI) was to provide technical support to the Department of Hawaiian Home Lands (DHHL) and two sets of their design/builders (Gentry and Habitat for Humanity using a Honsador packaged design) to improve comfort and energy efficiency of homes built in their neighborhoods. The lessons learned can be applied to future houses constructed in this climate zone, offering the opportunity to further reduce Hawai‘i's dependence on imported oil and reduce greenhouse gas emissions.

This project's specific objectives included:

1. Characterize the energy performance of typical single-family homes built on lands administered by DHHL;
2. Evaluate Building Energy Optimization Tool (BEopt) software for its ability to estimate relative performance of design options in terms of site and source energy use, greenhouse gas emissions, and thermal comfort;
3. Evaluate the ease of use of performance simulations for detached residential design as a flexible compliance pathway for the new Hawai‘i State Energy Code based on International Energy Conservation (IECC) 2015 and create models that are minimally compliant to this code for the three DHHL house types;
4. Calibrate the computational models against the actual monitored energy use and temperatures gathered from the existing houses;
5. Identify and quantify potential future design strategies to exceed the new energy code and improve thermal comfort;
6. Estimate the size of a photovoltaic array that would achieve net-zero site energy;
7. Communicate these design strategies to DHHL, the designers, and the builders for consideration in future thousands of homes planned for development; and
8. Train advanced-level architecture and engineering students – the design professionals of tomorrow – in building monitoring, data analysis, and computer building performance simulation.

BACKGROUND: A key function of DHHL is to facilitate housing for native Hawaiian beneficiaries. In the past 20 years, DHHL has built over 2,590 homes. It currently owns over 200,000 acres of land on which it plans to construct another 875 homes over the next 5 years. DHHL is the only housing developer in Hawai‘i dedicated to providing new homes to Hawaiian families. Historically, the homes have been adequate and affordable, but DHHL has not provided aggressive standards for building performance beyond code and there has been no post-occupancy work done to evaluate the energy performance or the level of occupant comfort in the various house types that have been constructed and occupied.

PROJECT STATUS/RESULTS: This study demonstrated how to improve the design of three typical house types in Hawai‘i: fully air-conditioned, partially air-conditioned, and naturally ventilated (no air-conditioning). It was conducted from June 2017 to April 2019 and consisted of three components: monitoring existing houses, creating energy simulation models, and making design recommendations. The monitored houses, located in the DHHL neighborhood of Kaneheli in Kapolei, O‘ahu, were built between 2009 and 2017 when the Hawai‘i energy code was based on the IECC 2006 energy code. A team of researchers at ERDL used construction documents, field notes, and other information to create energy simulation models of the three house types. The houses were sub-metered for a year and the data were used to validate the energy models. These three existing-house models were modified to be minimally compliant to the new Hawai‘i energy code based on IECC 2015. Some features were upgraded and others were downgraded to minimally meet the code.

For each house type, whole building energy models representing the following cases were compared: 1) existing house; 2) house minimally compliant with IECC 2015; 3) sensitivity studies for individual design variables; 4) house with combined energy efficiency measures; and 5) house with on-site renewable energy generation for net-zero energy performance.

The IECC 2015 models were used as a baselines to compare how different energy conservation measures (ECMs) would individually affect the predicted annual energy consumption. A combination of ECMs were then selected by the research team to create a "combined strategy" model for each house type. The simulation models for the naturally ventilated house were also assessed for thermal comfort.

In a hot and humid climate, thermal comfort is a major driver in determining the energy consumption of a home and the satisfaction of the occupants. For fully air-conditioned homes, cooling is the single largest end-use of energy: 40% to 54% of annual consumption for homes in this study. For naturally ventilated homes, improving thermal comfort will improve the occupants' experience and reduce the likelihood that air-conditioning will be retrofitted into the house.

Based on the parametric analyses, the team selected the energy efficiency measures at the point of diminishing returns and anticipated acceptability by builders and residents. These were inputs to an energy model named "Combined Measures" for each house type. As compared to the IECC 2015 base case, the selected measures and their combined annual energy reductions ranged from 23.5% (for naturally ventilated homes) to 41.1% (partially air-conditioned) to 47.3% (fully air-conditioned).

Additionally, the investigation into the energy consumption of typical DHHL building types has benefits for the general understanding of residential building strategies in Hawai'i and this climate zone and supports DHHL's mission of providing affordable housing over its full life-cycle.

Overall, this initiative successfully:

- Trained UH system students in energy monitoring and building simulation;
- Resulted in quantified recommendations for design and operation of high-performance and net-zero site-built and packaged housing units;
- Quantified the savings from energy efficient and net zero options for 1,000 site-built and packaged homes; and
- Developed building simulation models to evaluate multiple building scenarios.

The majority of this project was substantially completed by November 2019 with the results of this study being summarized in the technical report: "**Methods for Establishing and Validating Architectural Models to Analyze Building Performance of Existing Conditions and Simulated Design Options for Three Department of Hawaiian Homeland Residential Buildings in Kapolei, O'ahu, Hawai'i**".

However, dissemination of the results continued into 2020 with the creation of an abbreviated summary of results titled "**Going Beyond the New Hawai'i Energy Code**" aimed towards architects and design professionals and the writing of the peer reviewed paper: **Going Beyond Code: Monitoring Disaggregated Energy and Modeling Detached Houses in Hawai'i**, published in the *Buildings* journal.

The findings derived from this study were also used in an online webinar "**Zero Energy Home Design**," sponsored by the Hawai'i State Energy Office (HSEO) on December 2, 2021. The webinar provided guidance on net zero energy design for architects, contractors, and others involved in low-rise residential development.

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