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Methods to Monitor and Simulate Existing Residences: Analyzing and Improving Energy and Comfort for Native Hawaiian Homeowners

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Methods to Monitor and Simulate Existing Residences:

Analyzing and Improving Energy and Comfort for Native Hawaiian Homeowners

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Abstract

To support the State of Hawaii's goals of improving energy performance of buildings and reducing dependence on fossil fuels, this study develops design recommendations that could improve the energy efficiency and thermal comfort of hundreds of existing and future homes for native Hawaiian families.

This poster shares the methods and learning objectives used by faculty, researchers, and a team of architecture, electrical and mechanical engineering, and computer science students to chart a path to net-zero site energy use in residences in sub-tropical climates by monitoring and simulating existing houses.

The faculty from Architecture and Sea Grant structured the research project into multiple phases over two years: 1) Monitor Existing Buildings; 2) Calibrate Simulated Whole Building Energy Models; 3) Simulate Potential Design for Future Energy Code; 4) Simulate Potential Energy Efficiency Improvements; 5) Estimate Potential Renewable Energy Production and; 6) Communicate Recommendations to Developers and Residents.

In this study, three existing house typologies are studied: naturally ventilated (no air conditioning); partially air-conditioned; and centrally air-conditioned.

Student and senior researcher teams monitor and manage data for temperature, humidity, and sub-metered for electricity in nine houses for one year. Air conditioning comprises a larger portion of the monitored houses' total energy use as compared to national hot-humid climate residential averages. The monitored data shows most occupants chose to use air conditioning year round despite the mild climate and high electricity rates. In addition, monitored data shows plug loads vary between houses by more than a factor of two.

Student researchers using computational building performance simulation in NREL's BEopt with Energy Plus find that the most effective energy efficiency measures are 1) improving the air conditioning SEER rating and 2) increasing the thermostat cooling setpoint while using ceiling fans with occupancy sensors. The team graphically communicates recommendations and presents them to developers and homeowners for potential incorporation into the next hundreds of homes planned for construction.

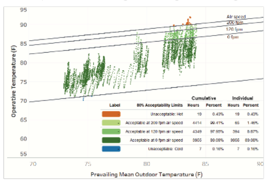
Keywords: Energy Efficiency, Residential, Sub-tropical, Thermal Comfort, Energy Simulation

Acknowledgements

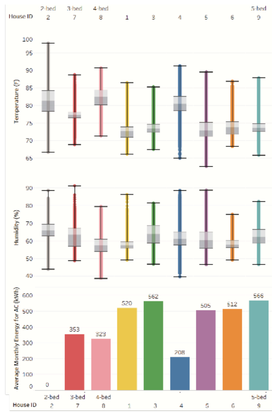
Thank you to Hawaii Natural Energy Institute as well as University of Hawaii Sea Grant College Program for funding to support staff, student researchers, and equipment.

01 Monitor Existing Residences

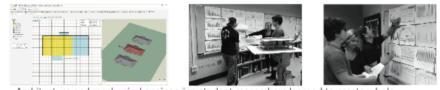
The team worked with a major home developer for native Hawaiian families to improve energy conservation and thermal comfort in existing and hundreds of future homes. This helps meet the State's greenhouse gas reduction goals.



The computer science students learned about thermal comfort by developing a script to plot the monitored temperatures in an adaptive comfort graph for the naturally ventilated house. The graph also quantified the hours that could made comfortable by increasing air speeds.

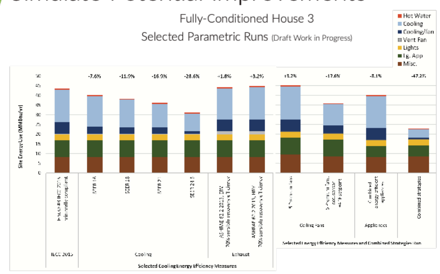


After monitoring the temperature, humidity, and disaggregated energy use for about a year, we see significant cooling energy savings with natural ventilation (house 2) or mixed-mode ventilation (house 4).



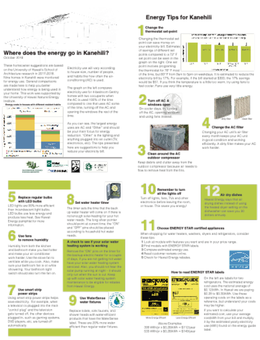
Architecture and mechanical engineering student researchers learned to create whole-building energy models using NREL's BEopt program with EnergyPlus. Students learned energy model calibration techniques, energy codes, and thermal comfort standards.

02 Simulate Potential Improvements



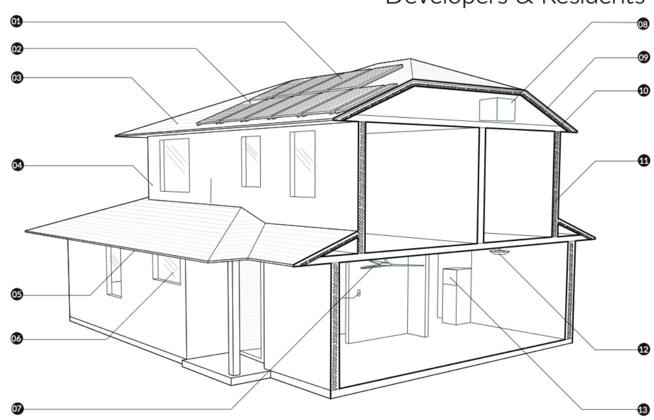
Students learned energy modeling steps including: 1) Calibrate; 2) IECC 2015 Base Case; 3) Parametric Options; 4) Combined Strategies Design Case. The most effective energy efficiency measures were improving the air conditioning SEER rating as well as increasing the cooling temperature setpoint while using premium efficiency ceiling fans with occupancy sensors.

03 Communicate Recommendations to Developers & Residents



Brochure for Residents

Based on the analysis, students and senior researchers presented energy conservation recommendations to homeowners using the brochure above.



Potential Energy Efficiency Strategies

Fully Air-conditioned House

After creating the simulated Design Case, and calculating the photovoltaic panels to achieve net-zero site energy, students created section perspective drawings to facilitate discussions with the developer and builders.

- 01 **Photovoltaic Panels**
- 02 **Solar Hot Water Panels**
- 03 **Light Colored Roof Material**
  Reflectance: >0.70
- 04 **Light Colored Exterior Finish**
  Absorptivity: <0.3
- 05 **3' Eaves**
- 06 **Window Type**
  Clear, Air-Filled, Double Pane, SHGC: 0.25 U-value: 0.5
  90% free area
- 07 **Ceiling Fan, Thermostat Offset**
  Premium efficiency fans w/ occupancy sensors. Four degree Farenheit thermostat cooling set-point increase.
- 08 **Air Conditioning Unit**
  SEER 24
- 09 **Radiant Barrier and Air Space**
- 10 **Roof Insulation**
  R-19
- 11 **Wall Insulation**
  R-13, Wood studs
- 12 **Lighting**
  100% LED Fixtures
- 13 **Appliances**
  Energy Star Refrigerator (with top freezer);
  Energy Star Washer and Dryer;
  Electric Stove - Premium

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To support the State of Hawaii's overarching goals of improving energy performance of buildings and reducing dependence on fossil fuels, this study develops design recommendations that could improve the energy efficiency and thermal comfort of hundreds of existing and future homes for native Hawaiian families living in developments by the Department of Hawaiian Homelands.

This poster shares the methods used by faculty and a team of architecture, electrical and mechanical engineering, and computer science students to chart a path to net-zero energy use in sub-tropical climates by monitoring and simulating existing residences.

The faculty from Architecture and Sea Grant structured the research project into multiple phases over two years: 1) Monitor Existing Buildings; 2) Calibrate Simulated Models; 3) Simulate Potential Designs for Future Energy Code; 4) Simulate Potential Energy Efficiency Improvements; 5) Estimate Potential Renewable Energy Production and; 6) Communicate Recommendations to Developers and Residents.

In this study, three existing home typologies are studied: naturally ventilated (no air conditioning); partially air-conditioned; and centrally air-conditioned.

Methods used and preliminary results for the monitoring portion of the project are as follows.

1 - After recruiting nine homeowner volunteers, the student and senior researcher team install sensors to measure temperature, humidity, and sub-meters for electricity for one year. Students learn to manage large quantities of data, create graphs for ASHRAE thermal comfort standards, and compare energy use intensity to similar residential developments.

2 - The monitored data allows the researchers to compare the houses to national averages and to each other in terms of energy use intensity and energy consumption by end use. In the monitored houses, air conditioning comprises a larger portion of the houses' total energy use as compared to national hot-humid climate residential averages.

3 - The monitored data gave insight into occupant behaviors that are not obvious from national averages. The monitored data shows most occupants chose to use air conditioning year round, even though mixed-mode ventilation yields significant cooling energy savings and similar indoor temperature and humidity. In addition, monitored data shows plug loads vary between houses by more than a factor of two.

Methods used and preliminary results for the simulation portion of the project are as follows.

1 - Student researchers learn to use computational building performance simulation to estimate existing and potential future reductions to house energy use and greenhouse gas emissions. Students researchers learn user-friendly software, NREL's BEopt with Energy Plus and Microsoft Excel.

2 - Students estimate on-site renewable energy production for net-zero site energy through hand calculations and PV Watts.

3 - The team develops recommendations and presented them to developers and homeowners. The team found that improving the air conditioning SEER rating and increasing the thermostat cooling setpoint while using ceiling fans were the most effective energy efficiency measures. We are hopeful that effective strategies will be incorporated into the next hundreds of homes built.

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