GOING BEYOND THE NEW HAWAIʻI ENERGY CODE

Lessons learned from monitoring and simulating seven houses in Kapolei, Oʻahu

2020 FALL //

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A typical, centrally air-conditioned house in Honolulu can save more energy than the current energy code requires. How? Can energy-saving changes be economical for the homeowner?

To answer these questions, a research team at the University of Hawai‘i monitored houses in a development in Kapolei, O‘ahu, Hawai‘i and collected new information on how energy is being used. The team created whole-building energy models to estimate one house’s annual energy use, first with the prescriptive requirements of the International Energy Conservation Code (IECC) 2015, the current code in Hawai‘i as of 2020. Next, individual energy efficiency measures were simulated separately, then combined into two cases.

The energy-optimized case is estimated to reduce annual energy use by 47.1% and annual energy cost by 39.6%, as compared to a similar house that minimally meets the IECC 2015. The cost-optimized case is estimated to reduce annual energy use by 45.5% and annual energy cost by 45.3%. Further information can be found in a published journal article by Meguro et al. 2020. https://doi.org/10.3390/buildings10070120

Neighborhood
Kanehili, Dept. of Hawaiian Home Lands

Builder
Gentry Kapolei Development, LLC

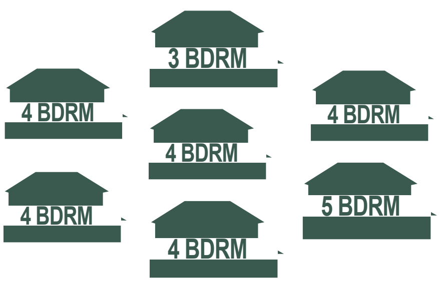
Years built
2008-2015

Code at time of build
IECC 2006

Year monitored
mid-2017 to mid-2018

UH Architecture students reviewing simulation results.

Image Credit: Gentry Kapolei Development, LCC



7 Houses Monitored
One 3-Bedrooms; Five 4-Bedrooms;One 5-Bedrooms

1,527 ft^2 - 1,676 ft^2
Livable Area

2-8 Residents
No. Occupants

Conclusions from Monitoring 7 DHHL Houses in Kapolei

- Six out of seven homes ran the air-conditioning all of the time, regardless of the weather.
- Five out of seven homes maintained indoor temperatures under 74ºF, lower than simulation protocol temperatures of 75ºF (IECC 2015) or 76ºF (Building America).
- Air-conditioning accounted for 40% to 54% of total annual energy use.
- Energy use intensity ranged from 12.8 kBtu/ft2/year to 29.2 kBtu/ft2/year (3.7 kWh/ft²/year to 8.5 kWh/ft²/year).
- Annual energy bills $1,832 to $4,153 (excluding PV production).

How Do Energy Efficiency Measures Stack Up?

The whole-building energy model represents a 4-bedroom house with changes to make it minimally meet the IECC 2015 code. The IECC 2015 model was further changed one factor at a time to determine the impact of various energy efficiency measures. Figure 1 shows the annual energy savings (%) for each energy efficiency measure. These results determined which options would be included (indicated with *) in the optimization simulation.

LEGEND

- **A** HVAC SEER 14 to 16*
- **B** HVAC SEER 14 to 18*
- **C** HVAC SEER 14 to 21*
- **D** HVAC SEER 14 to 24.5*
- **E** Energy recovery ventilator
- **F** Heat recovery ventilator
- **G** Add five premium efficiency ceiling fans
- **H** Adding five ceiling fans, occupancy sensors, +4°F set-point*
- **I** Efficient appliance package*
- **J** Exterior siding color; med to light*
- **K** Roof color; med to light*
- **L** Eaves; 2 ft to 3 ft*
- **M** Add radiant barrier, double-sided*
- **N** Lighting 75% to 100% high efficacy*

* Indicates option was included in the optimization simulation

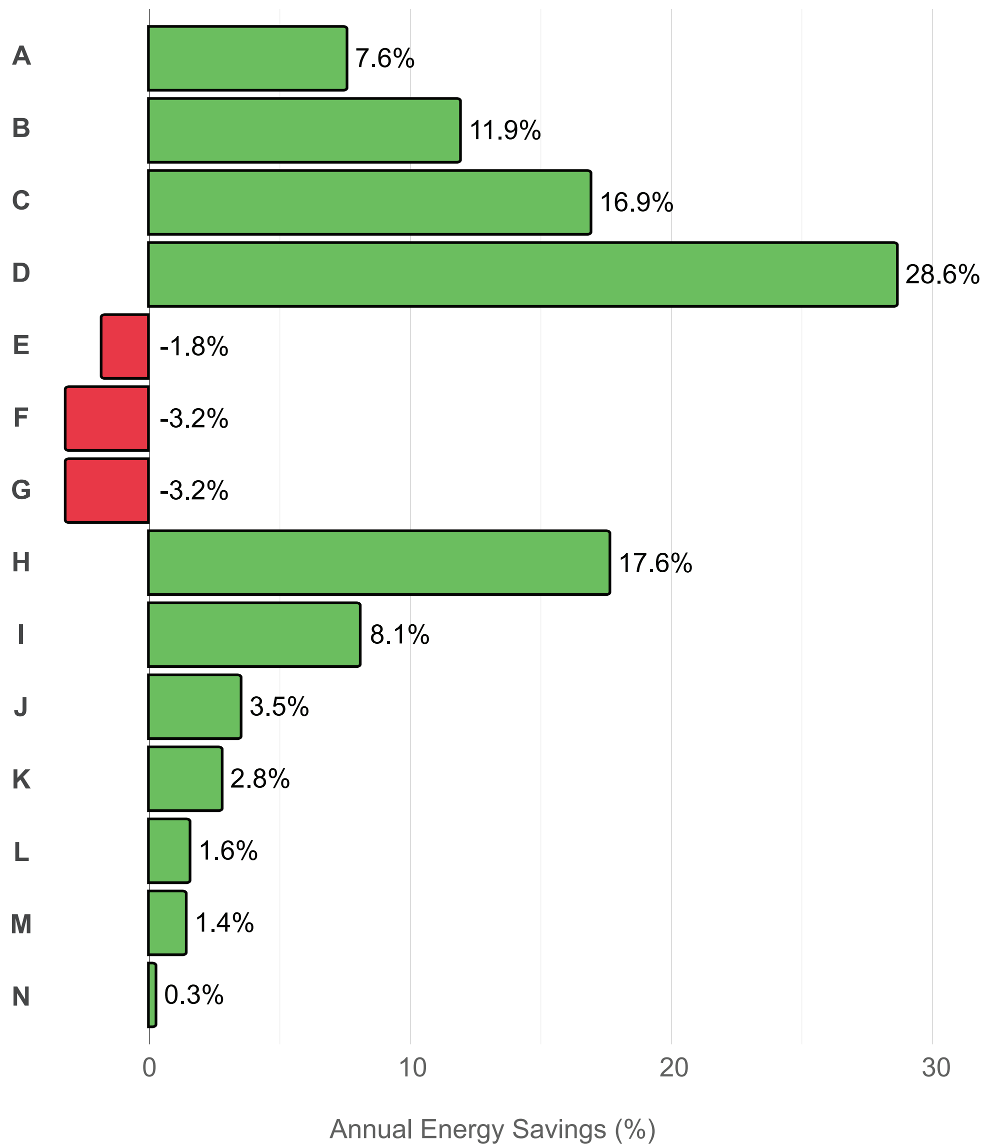


Figure 1. Energy savings results from parametric energy analysis compared to IECC 2015 baseline model

Performers

Best Performers

1. Of the measures tested, selecting a more efficient air-conditioning (AC) system reduced annual energy use the most. A seasonal energy efficiency ratio (SEER) rating of 24.5 was estimated to reduce annual energy use by 28.6% as compared to SEER 14.
2. Adding ceiling fans alone does not save energy, but coupling the ceiling fans with a 4ºF increase in AC thermostat setting and incorporating occupancy sensors to turn ceiling fans off was estimated to reduce annual energy use by 17.6% while still providing thermal comfort.
3. Selecting energy efficient appliances was estimated to reduce annual energy use by 8.1% and included:
    - Premium electric clothes dryer;
    - Energy Star compliant clothes washer;
    - An induction stove;
    - The refrigerator with a side freezer and ice dispenser was changed to an Energy Star compliant refrigerator with a top freezer and no ice dispenser.

Medium Performers

On the simulated house model, moderate annual energy savings were estimated for the following measures:

1. Lighter color exterior siding saved 3.5%;
2. Lighter color roof saved 2.8%;
3. Extending the roof eaves from 2 ft to 3 ft saved 1.6%;
4. Adding a double-sided radiant barrier to the roof saved 1.4%;
5. Improving the lighting efficiency from 75% LED to 100% LED saved 0.3%.

Poor Performers

On the simulated house model, little to no annual energy savings were estimated for the following measures:

1. Energy and heat recovery ventilators;
2. Changing the U-value of windows from 0.5 Btu/h-ft^2-°F to 0.4 or 0.3 Btu/h-ft^2-°F;
3. Increasing wall insulation from R-13 or the roof insulation from R-30.

What happens when we combine energy efficiency measures? And are they cost-effective?

The optimization simulation combines energy efficiency measures and identifies the combination with the lowest overall costs or the lowest annual energy use achievable for the lowest cost for that energy savings goal. The added costs to the mortgage (30-year) for the energy efficiency measures are included in the annualized energy-related costs of the optimized models.[1]

IECC 2015 baseline model

- This is our starting point and does not appear in Figure 2;
- Energy-related costs: $3,479 (utility bill).

The least-cost optimized model

- Has the lowest annualized costs, as shown circled in red in Figure 2;
- Reduced energy-related costs by 45.3% to $1,904/year (utility bill + added cost to mortgage);
- Saved $1,575/year compared to the IECC 2015 model.

The energy-optimized model

- Has the highest energy savings, as shown circled in blue in Figure 2;
- Reduced energy-related costs by 39.6% to $2,100/year (utility bill + added cost to mortgage);
- Saved $1,379/year compared to the IECC 2015 model.

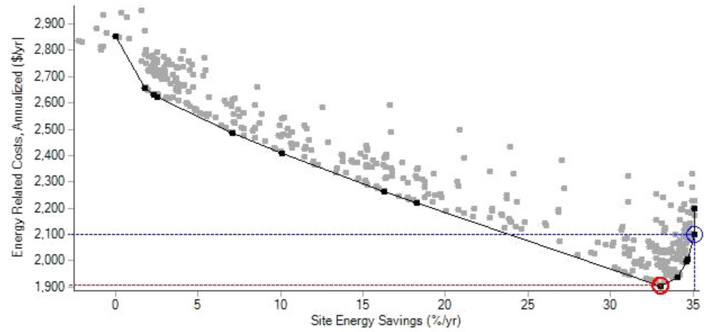


Figure 2. BEopt simulation output: energy savings vs annualized energy-related costs for all combinations of options tested. The least-cost optimized model is circled in red and the energy-optimized model is circled in blue

Table 1. Component differences of the three models

IECC 2015 Minimum Baseline Model Components	Least-Cost Optimized Model Components	Energy-Optimized Model Components
HVAC efficiency SEER 14	Variable speed HVAC SEER 24.5	Variable speed HVAC SEER 24.5
No ceiling fans cooling set-point 75°F	Five premium efficiency fans; occupancy sensors; increased the cooling set-point to 79°F	Five premium efficency fans; occupancy sensors; increased the cooling set-point to 79°F
Appliances: standard efficiency	Appliances: energy efficient, except stove is standard electric	Appliances: energy efficient including induction stove
Exterior finish: medium color	Exterior finish: light color	Exterior finish: light color
Eaves 2 ft	Eaves 2 ft	Eaves 3 ft
No radiant barrier	A double-sided foil radiant barrier	A double-sided foil radiant barrier
Roof material: medium color asphalt shingle	Roof material: medium color asphalt shingle	Roof material: white metal
75% high efficency lighting	100% LED lighting	100% LED lighting
Window U-value 0.5	Window U-value 0.4	Window U-value 0.5

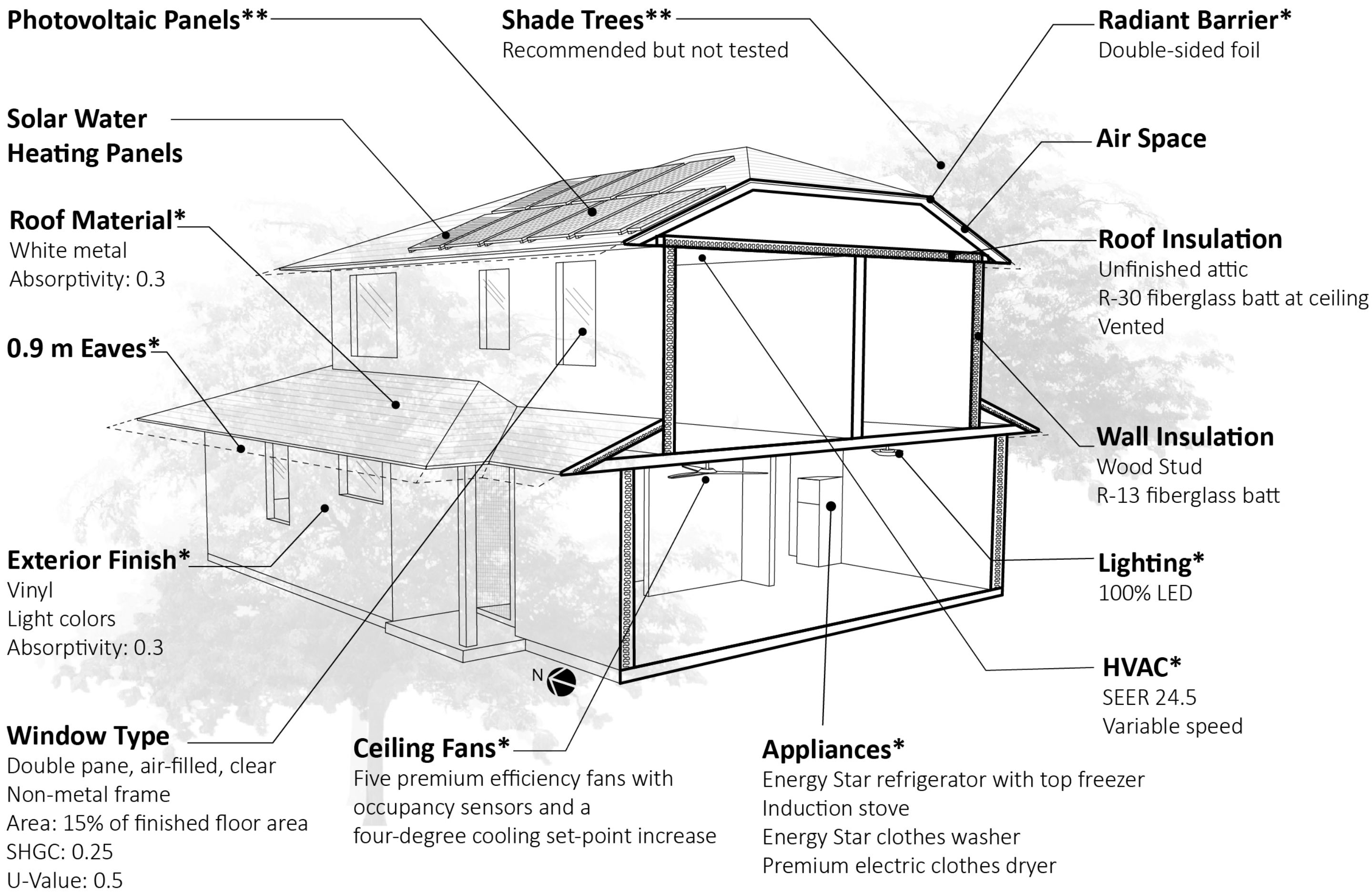


Figure 3. Energy-optimized model depiction: items with an asterisk (*) were modified from the IECC 2015 minimum energy model, whilst items the asterisks (**) were not modeled but are recommended for consideration.

Simulated annual energy use

Simulated annual energy use for the three models is shown in Table 2. Energy savings can be seen in the AC and large appliances. The resulting energy use intensities were:

- IECC 2015: 26.3 kBtu/ft^2/year (7.7 kWh/ft^2/year);
- Least-cost: 14.3 kBtu/ft^2/year (4.2 kWh/ft^2/year);
- Energy-optimized: 14.0 kBtu/ft^2/year (4.1 kWh/ft^2/year).

Table 2. Annual Energy use (kWh/year) disaggregated by end use for the three models.

End Use	IECC 2015 Minimum Model	Least-Cost-Optimized Model	Energy-Optimized Model
AC compressor	4,868	1,486	1,322
AC air handling unit	1,779	167	155
Large appliances	2,550	1,700	1,665
Miscellaneous	2,430	2,500	2,500
Lights	865	832	832
Water heating	170	164	167
Ventilation fan	108	108	108
Total energy use	12,770	6,957	6,749

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For more information on this research, see the peer-reviewed journal article:

Meguro, W., E. Peppard, S. Meder, J. Maskrey and R. Josephson. 2020. Going Beyond Code: Monitoring Disaggregated Energy and Modeling Detached Houses in Hawai‘i. *Buildings* 2020, 10(7), 120. https://doi.org/10.3390/buildings10070120

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Notes
[1]Economic Assumptions for Optimization Analysis: Energy-related costs are annualized over a 30-year period in the analysis and include: utility bills; costs of adding efficiency measures to the mortgage payment; and present value of future replacement costs for options with lifetimes less than the analysis period. Costs in BEopt are based on U.S. national average data, but cost multipliers for Hawai‘i were used.

Inflation rate: 2.4%
Discount rate: 3.0
Utility rate used: $0.2961/kWh average
Cost multiplier for materials: 1.32
Cost multiplier for labor: 1.43
Size of house: 1,654-ft^2, 4-bedroom

References
Wilson, E.; Metzger, C.E.; Horowitz, S.; Hendron, R. 2014 Building America House Simulation Protocols. Available online: https://www.nrel.gov/docs/fy14osti/60988.pdf (accessed on 26 June 2020).

International Code Council. 2015 International Energy Conservation Code-Third Printing; International Code Council, Inc.: Washington, DC, USA, 2016; ISBN 9781609834869.