Zero Energy Home Design

HAWAII STATE Energy Office

Webinar
December 2, 2021

Presentation Collaborators

Hawai'i Energy, School of Architecture, Honolulu Section, BIA, ASHRAE Hawaii Chapter, AIA Honolulu, HAWAII, HNEI, Sea Grant, BOMA Hawaii

Net-zero concept

Motivations

PV system primer

How homes use energy in Hawai'i

The energy code,
the starting point for efficiency

Beyond-code efficiency strategies

Integrating PV
and batteries

Hawaii
Energy

Wrap
Up

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Hawai'i Energy · School of Architecture, University of Hawai'i at Mānoa · IES Honolulu Section · BIA Building Industry Association Hawaii · ASHRAE Hawaii Chapter · Environmental Research & Design Lab · AIA Honolulu · USGBC Hawaii · HNEI Hawai'i Natural Energy Institute, University of Hawai'i at Mānoa · Sea Grant · BOMA Hawaii Building Owners and Managers Association

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

COURSE DESCRIPTION

This webinar provides guidance on net zero energy design for architects, contractors and others involved in low-rise residential development. Topics:

- Recent UH research on how Hawai'i homes consume energy
- Cost effective beyond-code energy efficiency strategies
- Integrating solar energy for net-zero performance
- Adding battery storage to shift electricity demand

The need for zero-energy homes is greater than ever as Hawaii transitions to 100 percent clean energy. The goal of this webinar is to aid in this transition with information that helps designers and contractors integrate efficiency, solar energy and energy storage. The guidance is informed by several research projects, including detailed monitoring and simulation of seven Hawaii homes [https://seagrant.soest.hawaii.edu/going-beyond-code/].

CONTINUING EDUCATION AIA

LEARNING OBJECTIVES

At the end of this course, participants will be able to:

1. Describe how Hawaii's homes, conditioned and unconditioned, consume energy
2. Identify cost-effective building envelope and AC efficiency strategies
3. Evaluate tradeoffs between water heating system alternatives
4. Plan for solar electric and battery systems in new home design

Introductions

Presenters

- Wendy Meguro, UH Manoa School of Architecture & Hawaiʻi Sea Grant
- Eileen Peppard, Hawai'i Sea Grant
- Rocky Mould, Hawaii Solar Energy Association
- Erik Kolderup, Kolderup Consulting
- Justin Bizer, Hawaii Energy

Acknowledgments

- Gail Suzuki-Jones, State Energy Office
- Howard Wiig, State Energy Office
- Kathy Yim, State Energy Office
- Sehun Nakama, Hawaii Energy
- Karen Shishido, Hawaii Energy

Topics

Net-zero concept

Motivations

PV system primer

How homes use energy in Hawai'i

The energy code, the starting point for efficiency

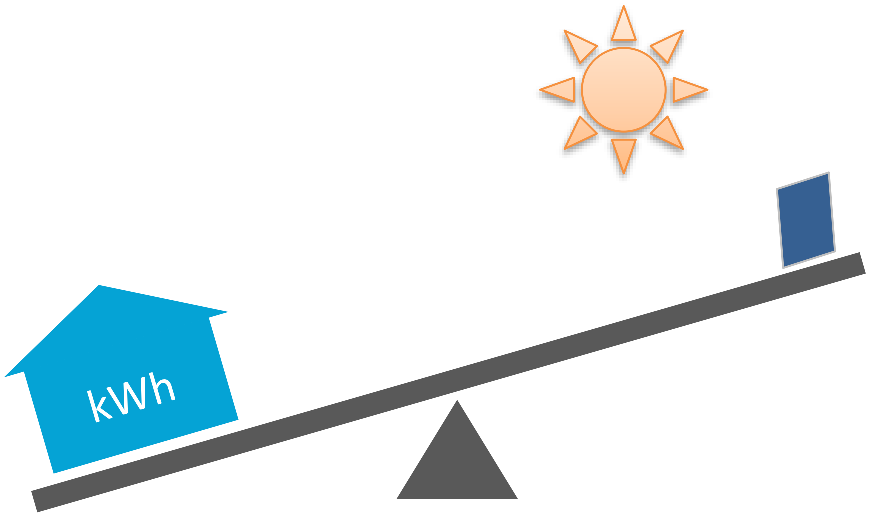
Beyond code efficiency strategies

Integrating PV and batteries

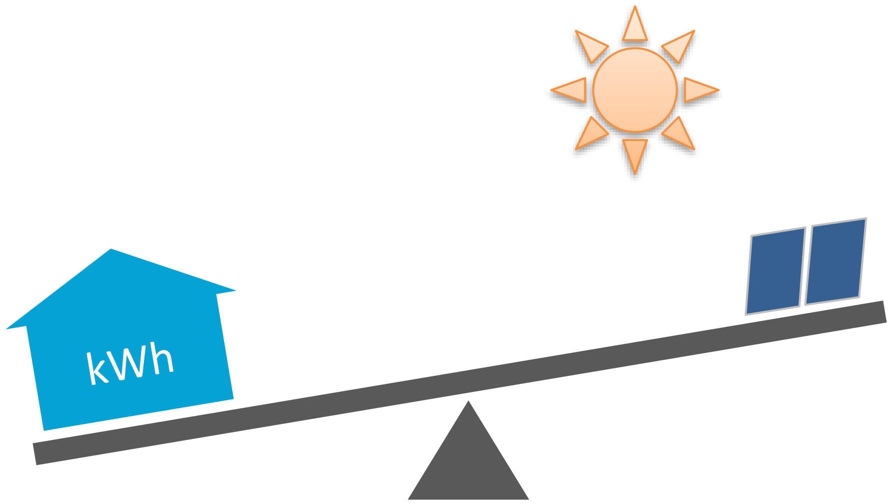
Hawaii Energy incentives

Net-zero concept

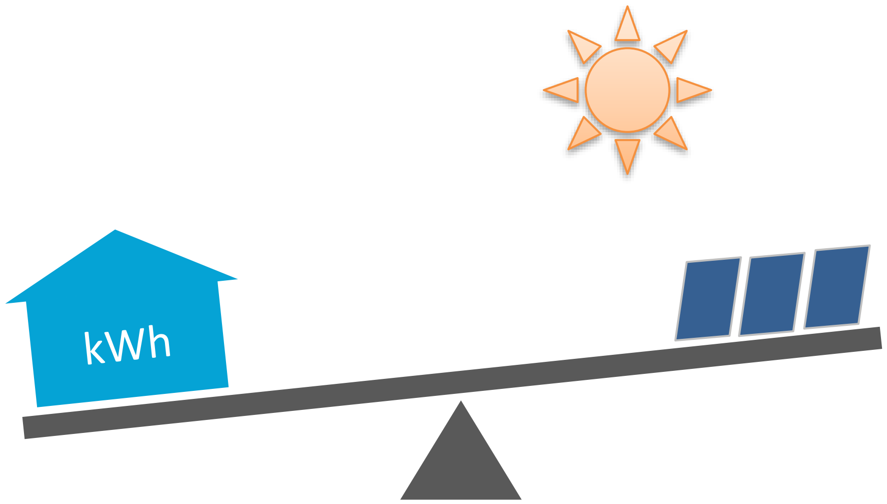
Net zero energy



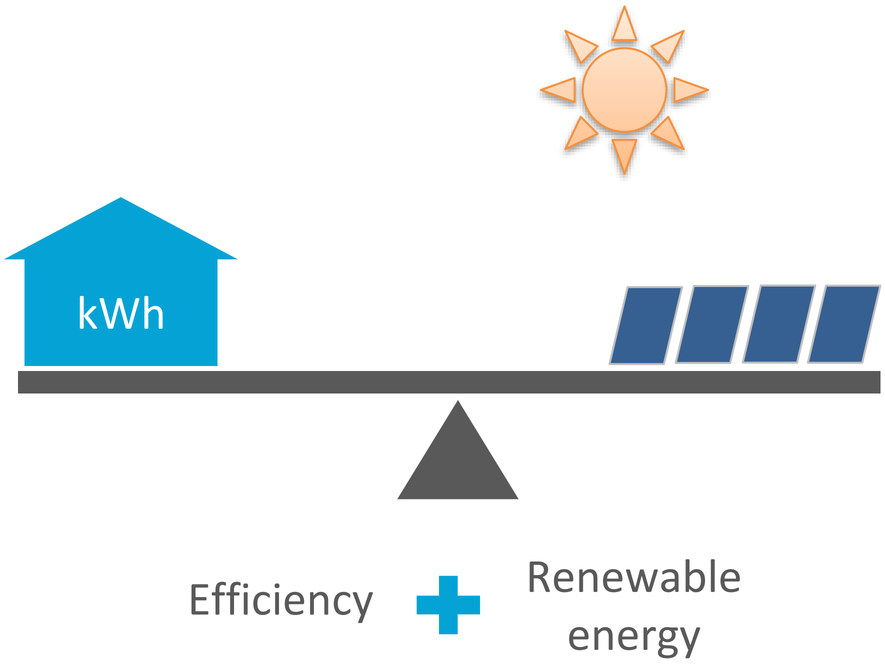
Net zero energy



Net zero energy

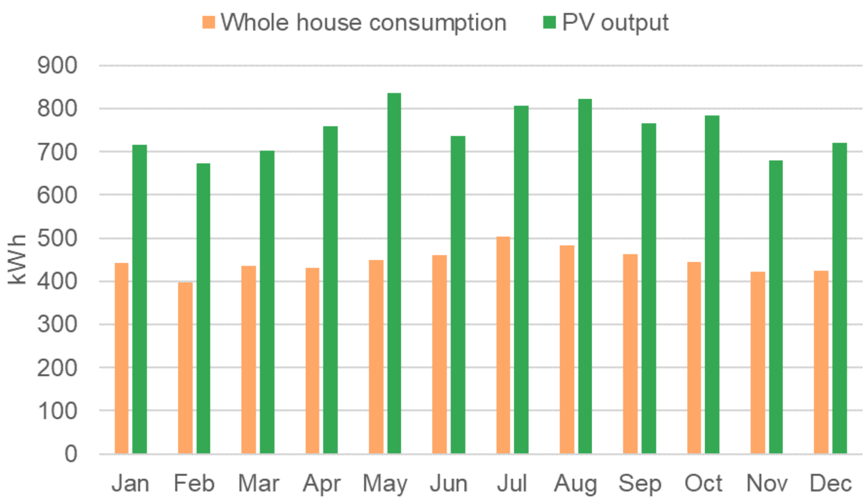


Net zero energy



Net zero energy

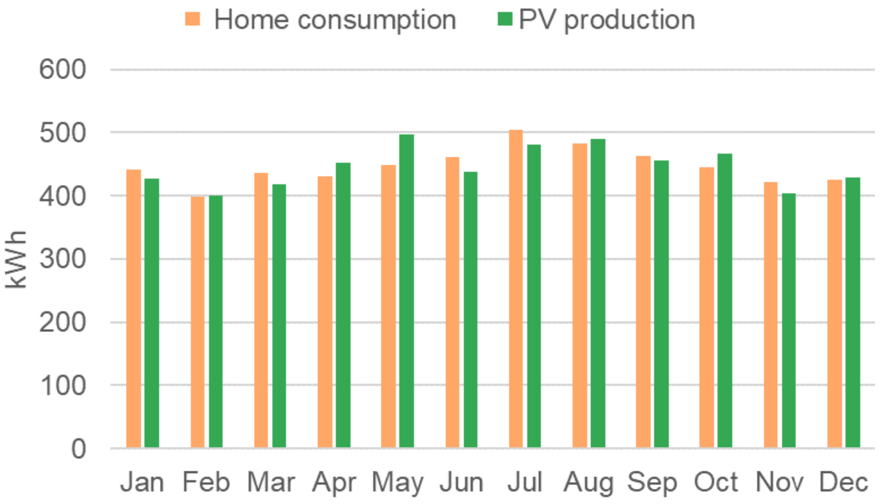
Annual balance

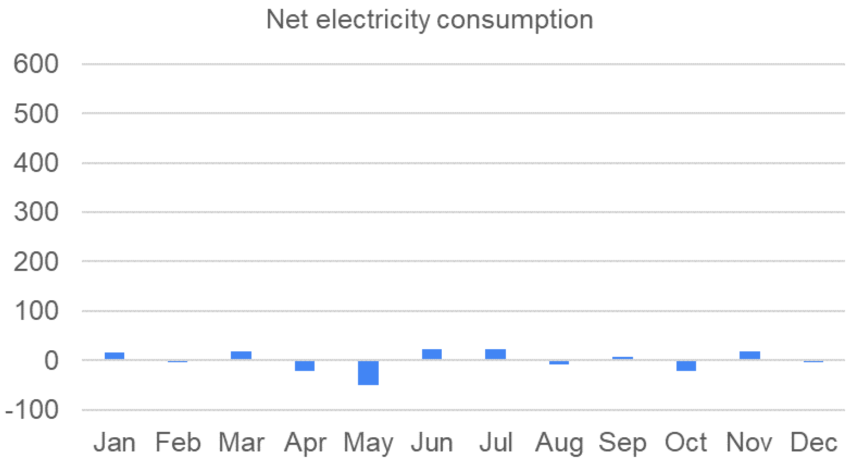


Rendering by Jeff Brink, edited by Darlyn Chau and Aiko Tells
2,270 ft² | Family of 4 | 4 BR
Armstrong Builders | LEED Platinum | NAHB Silver

Net zero energy

Annual balance

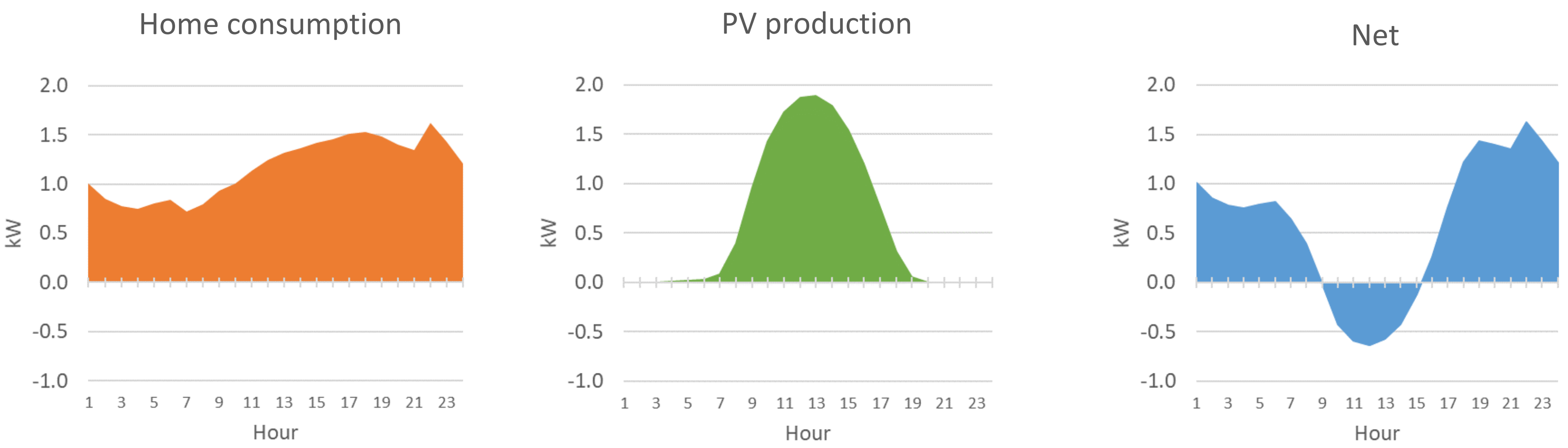




With PV results scaled down to equal home consumption

Net zero energy

Daily balance



Annual average daily profiles for four monitored homes

Net zero energy

Daily balance

Home consumption

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.7	0.8	0.8	1.0	0.9	0.8	1.0	1.1	1.0	0.8	0.8	0.9
1	0.7	0.6	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.7	0.8	0.8
2	0.6	0.5	0.6	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.6	0.8
3	0.6	0.6	0.6	0.7	0.8	0.7	0.9	0.8	0.9	0.7	0.6	0.7
4	0.7	0.6	0.7	0.8	0.8	0.7	0.9	1.0	0.9	0.7	0.7	0.7
5	0.8	0.7	0.7	0.9	0.9	0.8	1.0	1.0	0.9	0.7	0.8	0.8
6	0.7	0.5	0.6	0.7	0.9	0.7	1.0	1.0	0.8	0.7	0.8	0.7
7	0.7	0.7	0.7	0.9	0.8	0.9	1.0	1.0	0.8	0.8	0.8	0.7
8	0.7	0.7	0.8	1.0	1.0	1.1	1.3	1.1	1.0	0.9	0.8	0.6
9	0.8	0.8	0.9	1.0	1.0	1.2	1.2	1.2	1.1	1.1	1.0	0.7
10	1.0	0.8	0.9	1.1	1.2	1.2	1.4	1.3	1.3	1.1	1.1	0.7
11	1.1	0.9	0.9	1.1	1.2	1.3	1.6	1.5	1.4	1.1	1.1	0.8
12	1.0	0.9	0.9	1.1	1.3	1.4	1.5	1.5	1.4	1.1	1.1	0.8
13	1.0	0.9	0.9	1.0	1.3	1.4	1.6	1.5	1.4	1.2	1.2	0.9
14	1.1	0.9	0.9	1.0	1.3	1.4	1.6	1.5	1.5	1.3	1.3	0.9
15	1.1	0.9	1.0	1.1	1.4	1.4	1.6	1.6	1.5	1.3	1.2	1.0
16	1.1	1.0	1.0	1.2	1.3	1.4	1.6	1.8	1.7	1.3	1.3	1.0
17	1.1	1.0	1.0	1.3	1.2	1.4	1.8	1.8	1.7	1.3	1.4	1.1
18	1.2	1.0	1.0	1.2	1.3	1.4	1.6	1.8	1.6	1.1	1.3	1.1
19	1.2	1.1	1.1	1.3	1.3	1.3	1.6	1.8	1.6	1.1	1.4	1.2
20	1.3	1.2	1.2	1.4	1.2	1.2	1.7	1.7	1.4	1.1	1.2	1.3
21	1.2	1.2	1.3	1.4	1.4	1.2	1.6	1.7	1.4	1.1	1.2	1.3
22	1.1	1.1	1.2	1.3	1.3	1.2	1.5	1.6	1.3	1.2	1.1	1.3
23	0.9	0.9	1.0	1.2	1.1	1.0	1.3	1.3	1.1	1.0	0.9	1.1

PV production

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
7	0.1	0.1	0.3	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.3	0.1
8	0.7	0.5	0.7	0.8	1.0	1.0	0.7	0.8	0.9	1.0	0.9	0.7
9	1.2	1.0	1.1	1.3	1.4	1.5	1.1	1.2	1.3	1.5	1.4	1.2
10	1.6	1.4	1.5	1.6	1.6	1.7	1.4	1.4	1.6	1.7	1.7	1.4
11	1.9	1.6	1.7	1.8	1.8	1.8	1.6	1.6	1.7	1.8	1.8	1.6
12	1.9	1.7	1.7	1.8	1.8	1.9	1.6	1.7	1.8	1.8	1.8	1.5
13	1.8	1.6	1.7	1.8	1.7	1.7	1.6	1.6	1.7	1.6	1.7	1.5
14	1.6	1.4	1.5	1.5	1.4	1.5	1.3	1.4	1.6	1.3	1.4	1.3
15	1.3	1.2	1.2	1.2	1.1	1.2	1.1	1.1	1.2	1.1	1.0	0.9
16	0.8	0.8	0.8	0.8	0.7	0.9	0.7	0.8	0.7	0.7	0.5	0.5
17	0.3	0.3	0.4	0.4	0.4	0.5	0.4	0.4	0.3	0.2	0.1	0.1
18	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Net

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.8	0.8	0.8	1.0	0.9	0.8	1.0	1.1	1.0	0.8	0.9	0.9
1	0.7	0.6	0.7	0.9	0.8	0.8	0.9	0.9	0.9	0.7	0.8	0.8
2	0.6	0.6	0.6	0.8	0.8	0.7	0.8	0.8	0.8	0.7	0.6	0.8
3	0.6	0.6	0.6	0.7	0.8	0.7	0.9	0.8	0.9	0.7	0.6	0.7
4	0.7	0.6	0.7	0.8	0.8	0.7	0.9	1.0	0.9	0.7	0.7	0.7
5	0.8	0.7	0.7	0.9	0.9	0.8	1.0	1.0	0.9	0.8	0.8	0.8
6	0.7	0.5	0.6	0.7	0.8	0.6	0.9	0.9	0.8	0.6	0.8	0.7
7	0.6	0.6	0.4	0.5	0.4	0.4	0.7	0.7	0.4	0.3	0.4	0.5
8	0.1	0.2	0.1	0.2	0.0	0.1	0.6	0.3	0.0	-0.1	-0.1	0.0
9	-0.4	-0.2	-0.2	-0.3	-0.4	-0.3	0.1	0.0	-0.2	-0.4	-0.4	-0.5
10	-0.6	-0.5	-0.6	-0.5	-0.4	-0.5	0.0	-0.1	-0.3	-0.6	-0.6	-0.7
11	-0.8	-0.7	-0.8	-0.7	-0.6	-0.5	0.0	-0.1	-0.3	-0.7	-0.6	-0.8
12	-0.9	-0.8	-0.8	-0.7	-0.6	-0.5	-0.1	-0.1	-0.4	-0.7	-0.6	-0.7
13	-0.7	-0.7	-0.8	-0.8	-0.4	-0.3	0.0	-0.1	-0.3	-0.4	-0.5	-0.6
14	-0.5	-0.5	-0.6	-0.5	-0.1	0.0	0.3	0.1	-0.1	0.0	-0.1	-0.4
15	-0.2	-0.3	-0.2	-0.1	0.2	0.2	0.5	0.5	0.3	0.3	0.2	0.0
16	0.3	0.2	0.2	0.5	0.5	0.5	0.9	1.0	1.0	0.6	0.7	0.5
17	0.9	0.6	0.6	0.9	0.9	0.9	1.4	1.4	1.4	1.1	1.3	1.0
18	1.2	1.0	0.9	1.2	1.2	1.2	1.5	1.7	1.6	1.1	1.3	1.1
19	1.2	1.1	1.1	1.3	1.3	1.2	1.6	1.8	1.6	1.1	1.4	1.2
20	1.3	1.2	1.2	1.4	1.2	1.2	1.7	1.7	1.4	1.1	1.2	1.3
21	1.2	1.2	1.3	1.4	1.4	1.2	1.6	1.7	1.4	1.1	1.2	1.3
22	1.2	1.1	1.2	1.3	1.3	1.2	1.5	1.6	1.3	1.2	1.1	1.3
23	0.9	0.9	1.0	1.2	1.1	1.0	1.3	1.3	1.1	1.0	0.9	1.1

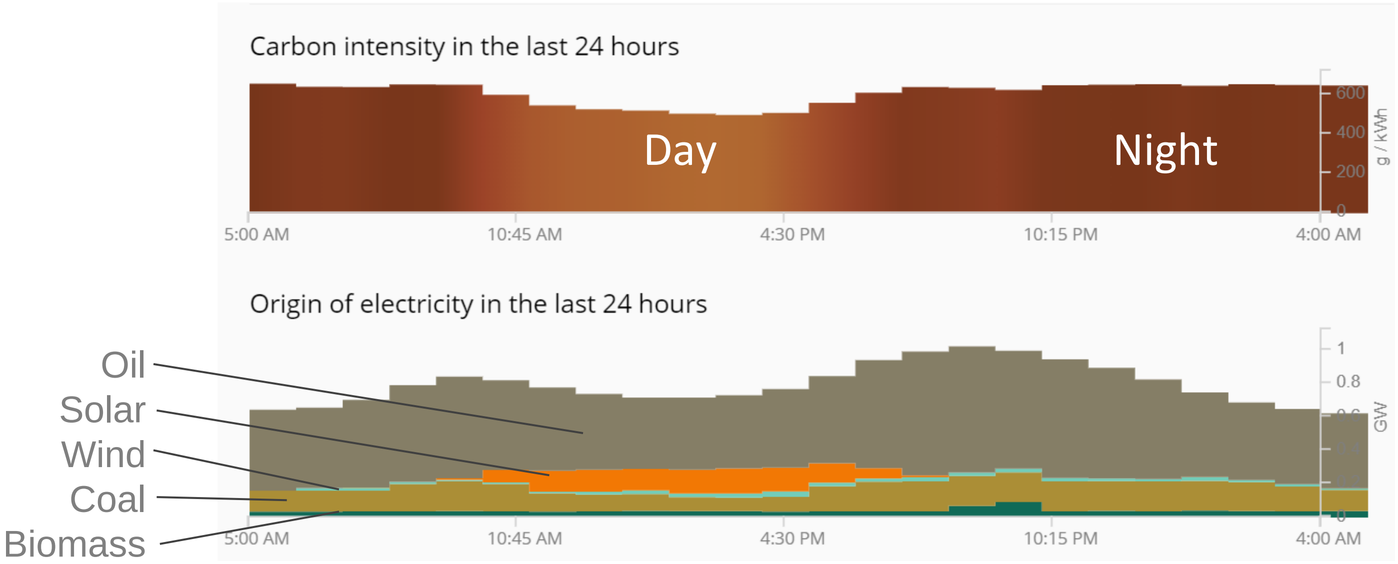
Monthly average daily kW profiles for four monitored homes

Beyond net zero energy goals

CO_2 emissions ➡

Load shifting

Oahu Electricity Carbon Intensity (g/kWh)
24-hour period, Nov 23/24, 2021

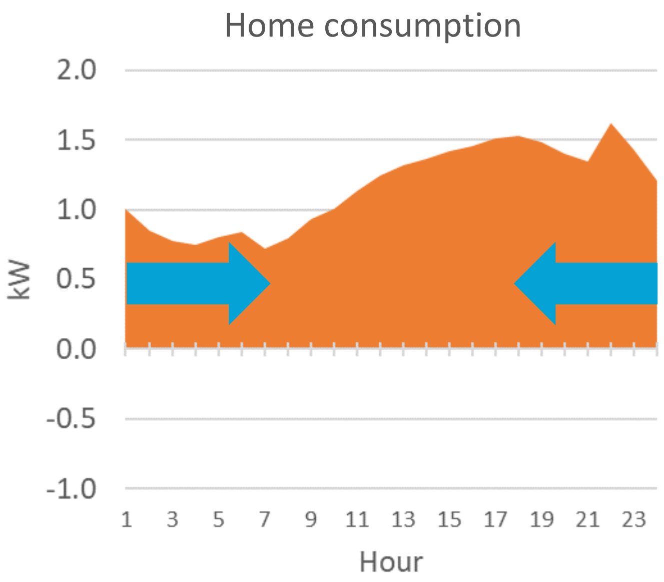


https://app.electricitymap.org/zone/US-HI-OA

Beyond net zero energy goals

CO_2 emissions

Load shifting



Motivations

Motivations

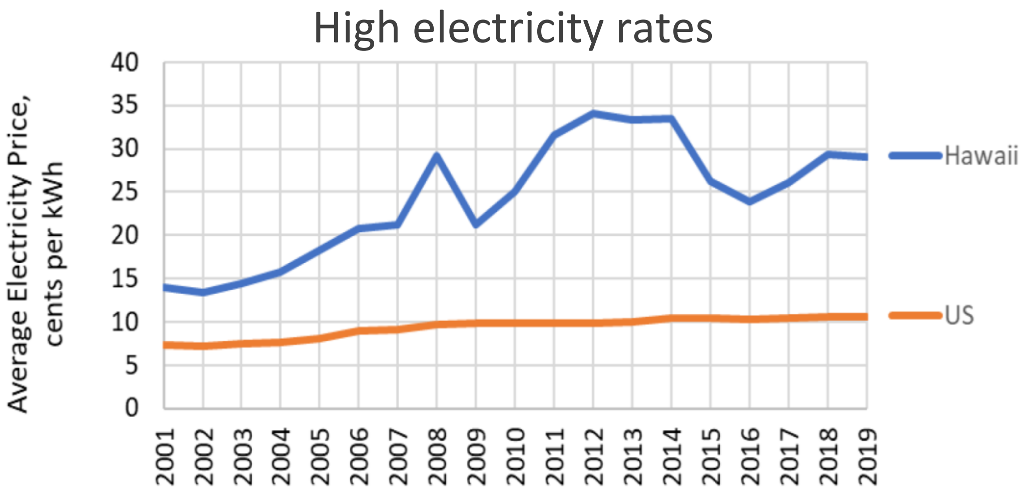
Reduce utility bills ➡

Reduce imported energy

Reduce climate impact

Support State goals

Single family home $2,500/yr average utility bill



Hawai'i's Energy Facts and Figures 2020, HSEO

Motivations

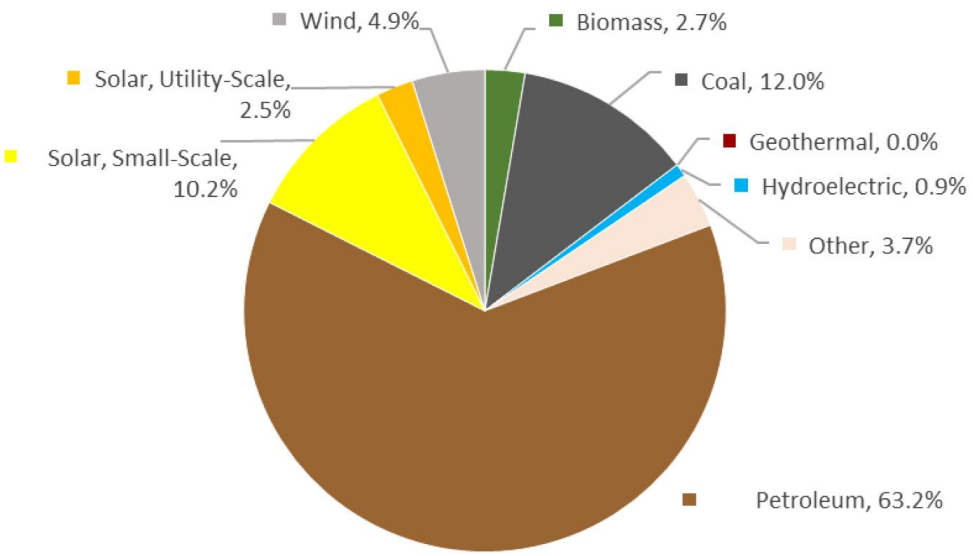
Reduce utility bills

Reduce imported energy

Reduce climate impact

Support State goals

Hawai'i electricity source (2019)



Hawai'i's Energy Facts and Figures 2020, HSEO

Motivations

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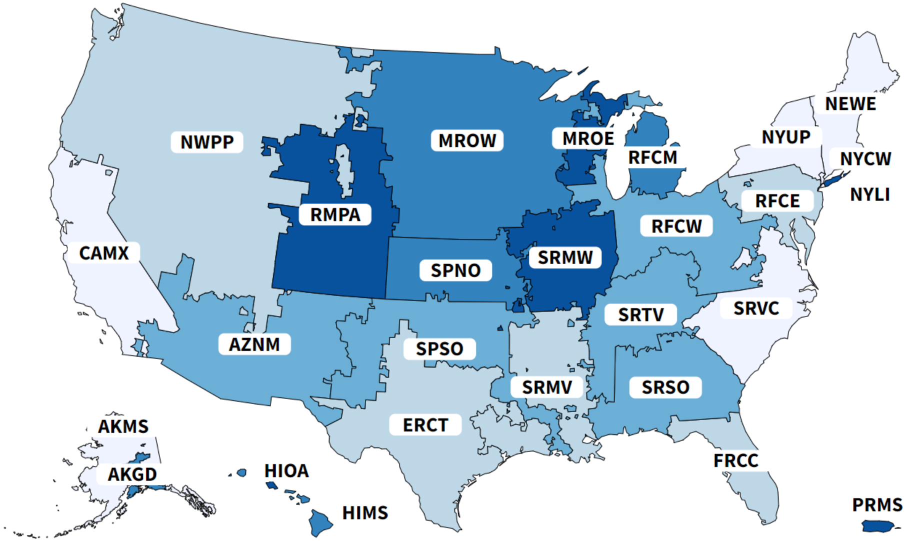
Support State goals

CO_2 total output emission rate (lb/MWh) by eGRID subregion, 2019



https://www.epa.gov/egrid

Motivations

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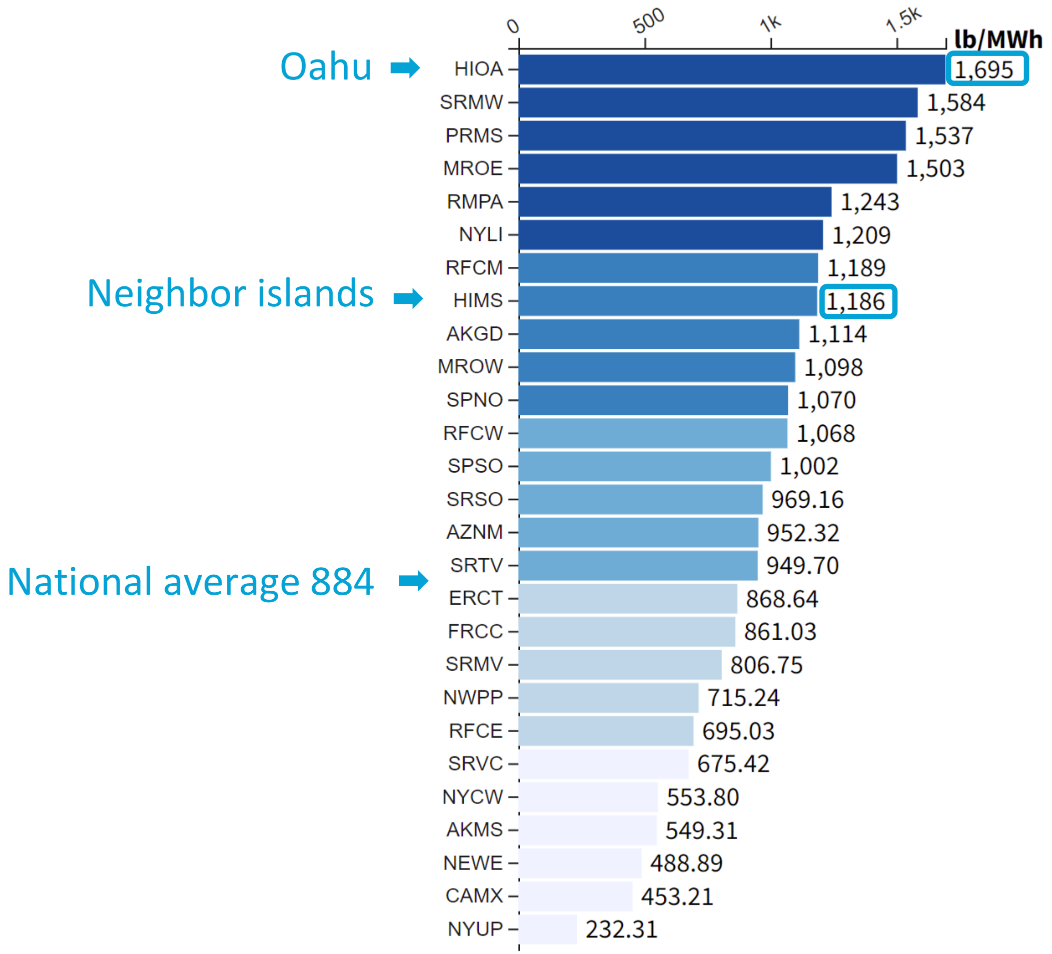

https://www.epa.gov/egrid

Motivations

Reduce utility bills

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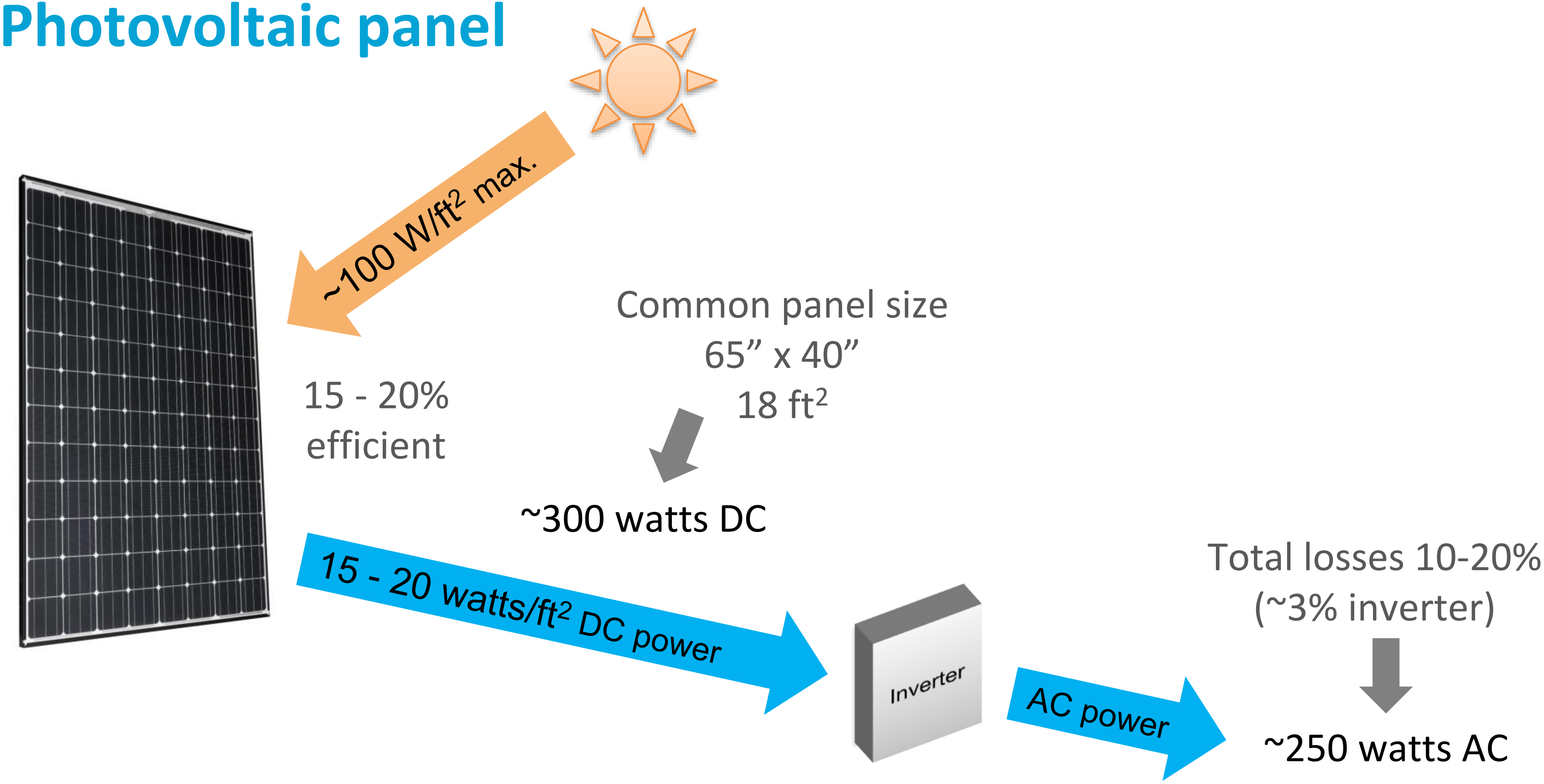
Support State goals ➡

Energy savings	2008 - Energy Efficiency Portfolio Standard (EEPS)	4300 GWh savings by 2030
Renewable energy	2015 - Renewable Portfolio Standard	40% renewable by 2030 70% by 2040 100% by 2045
Greenhouse gasses	2018 - HB2182	Net zero greenhouse gasses by 2045

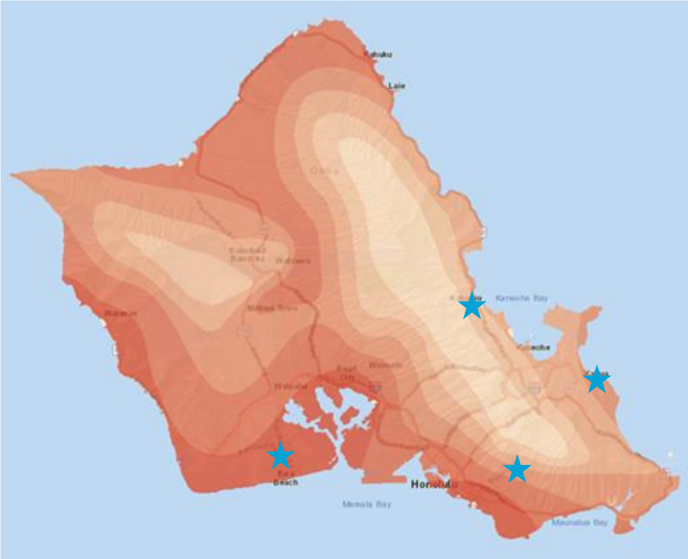
PV system primer

Photovoltaic panel

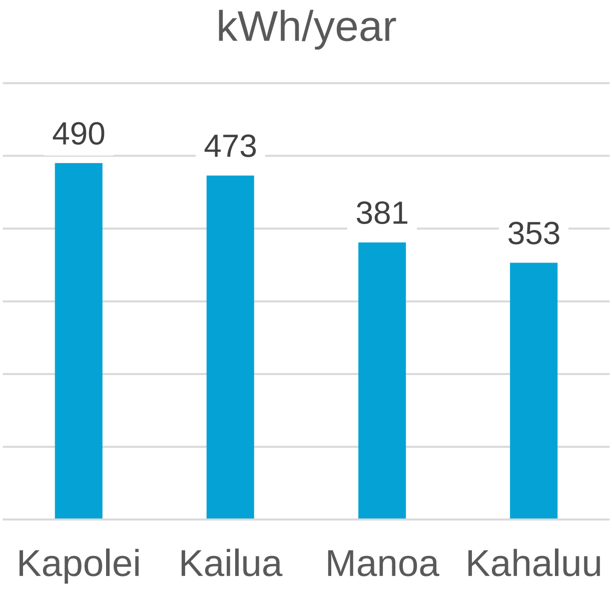


Photovoltaic panel

~300 watts

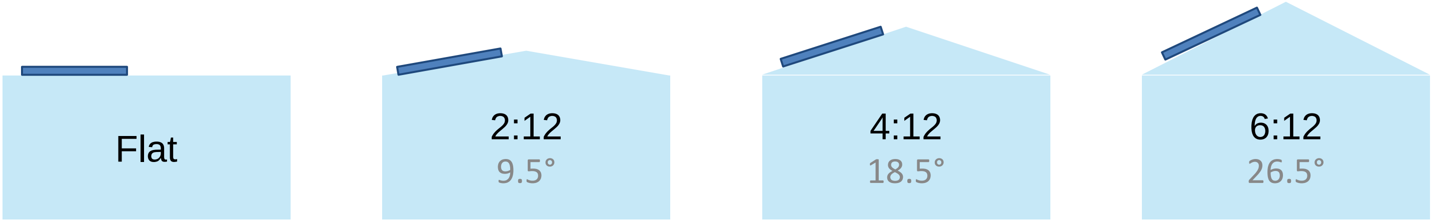


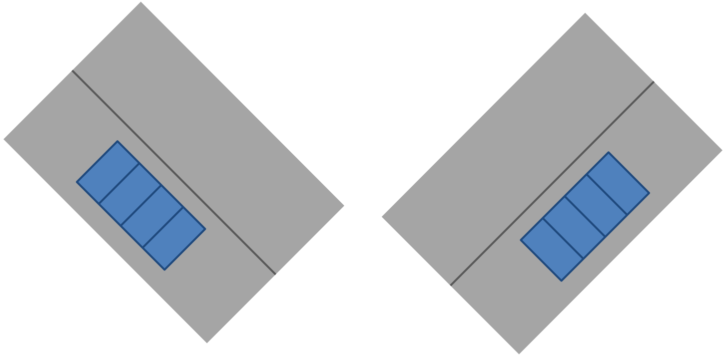
http://geodata.hawaii.gov/energis



https://pvwatts.nrel.gov
Facing south, 20° tilt

Tilt and Orientation





South Southwest Southeast West/East

PV Orientation and Tilt Impact

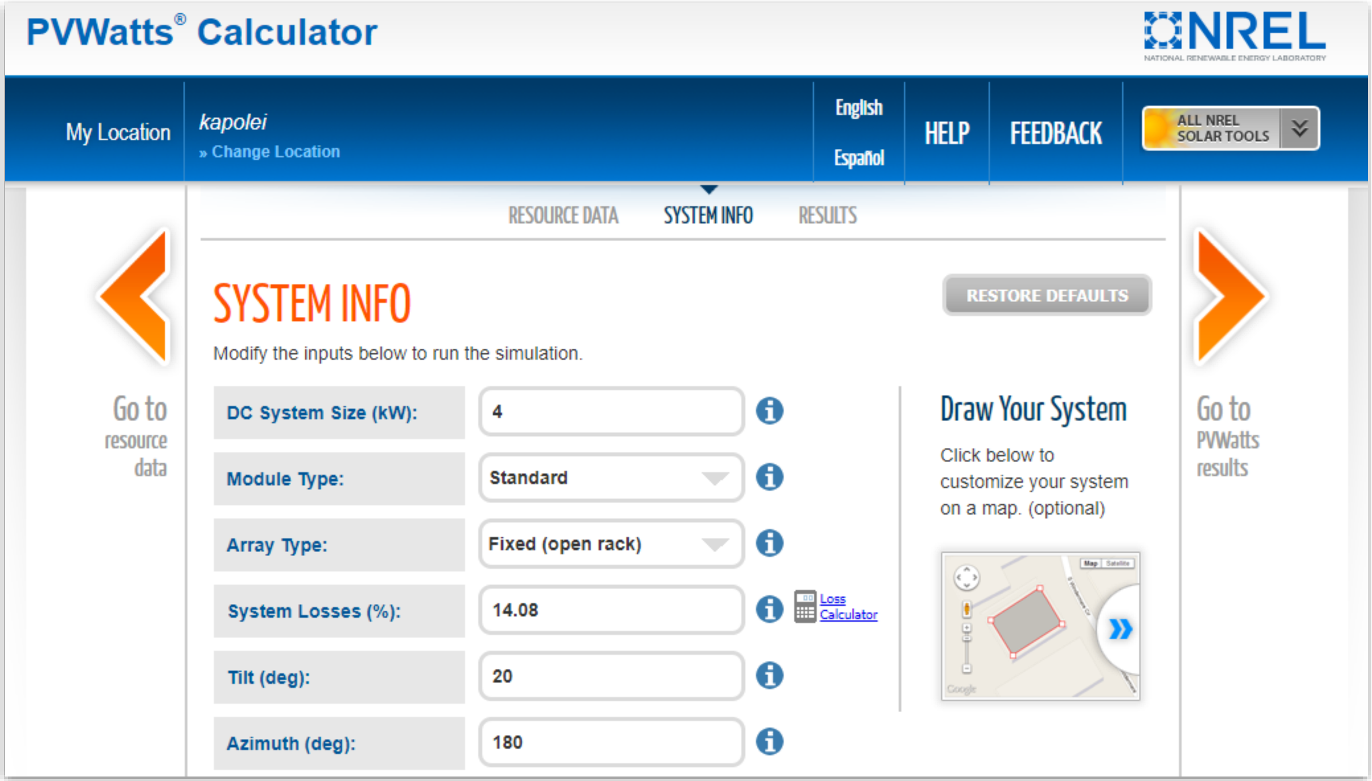
Orientation

		N	NW	W	SW	S	SE	E	NE	N
		0°	315°	270°	225°	180°	135°	90°	45°	0°
Horizontal	0°	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	10°	0.89	0.90	0.94	0.97	0.99	0.98	0.95	0.92	0.89
	20°	0.82	0.84	0.91	0.97	**1.00**	0.99	0.94	0.87	0.82
	30°	0.72	0.77	0.87	0.95	0.99	0.98	0.91	0.80	0.72
	40°	0.62	0.69	0.83	0.91	0.96	0.95	0.88	0.73	0.62
Tilt	50°	0.52	0.61	0.77	0.86	0.90	0.90	0.83	0.65	0.52
	60°	0.43	0.54	0.72	0.80	0.82	0.84	0.77	0.58	0.43
	70°	0.36	0.47	0.66	0.72	0.72	0.77	0.71	0.52	0.36
	80°	0.29	0.42	0.60	0.64	0.61	0.68	0.65	0.46	0.29
Vertical	90°	0.25	0.38	0.54	0.56	0.51	0.59	0.58	0.41	0.25

Roof pitch

- 1:12 = 4.5°
- 2:12 = 9.5°
- 3:12 = 14°
- 4:12 = 18.5°
- 5:12 = 22.5°
- 6:12 = 26.5°
- 8:12 = 33.7°
- 12:12 = 45°

Based on Kapolei, Oahu location and weather



https://pvwatts.nrel.gov

PVWatts® Calculator

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

My Location | *kapolei* » Change Location | English / Español | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

6,656 kWh/Year*

System output may range from 6,457 to 6,857 kWh per year near this location.
Click HERE for more information.

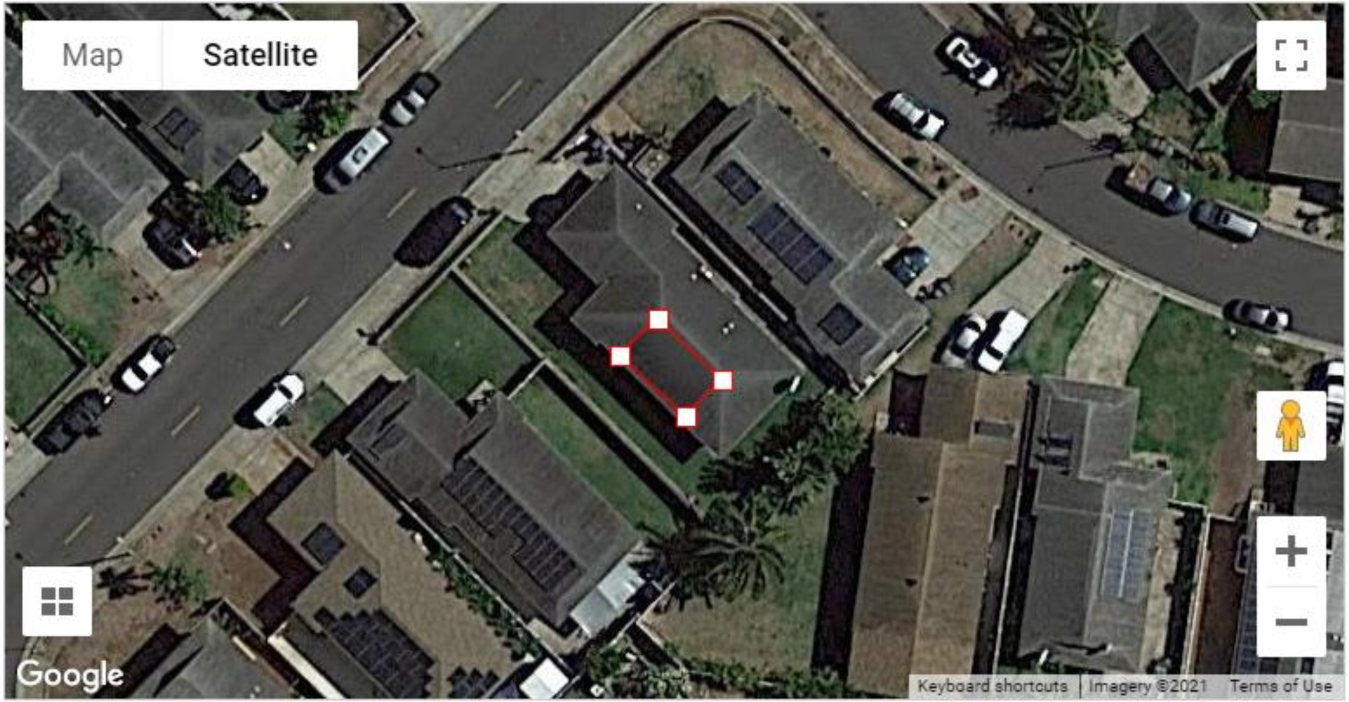
Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	5.50	521	183
February	5.93	506	178
March	6.32	589	207
April	6.31	583	205
May	6.16	576	202
June	6.08	546	192
July	6.30	592	208
August	6.47	605	212
September	6.27	569	200
October	6.08	569	200
November	5.51	499	175
December	5.21	500	176
Annual	6.01	6,655	$ 2,338

https://pvwatts.nrel.gov

Customize Your System To Your Roof

On the map below, click the corners of the desired system. Note that the roof tilt and azimuth cannot be automatically determined from the aerial imagery, and consequently the estimated system capacity may not reflect what is actually possible.

System Capacity: 4.5 kWdc (30 m2)



How homes use energy in Hawai’i

Kanehili Gentry Homes, DHHL, East Kapolei, 2009

Energy Monitoring and Simulation Study

Research Questions:

1) How is energy being used? (monitoring)
2) Can we recommend design improvements? (energy simulation)

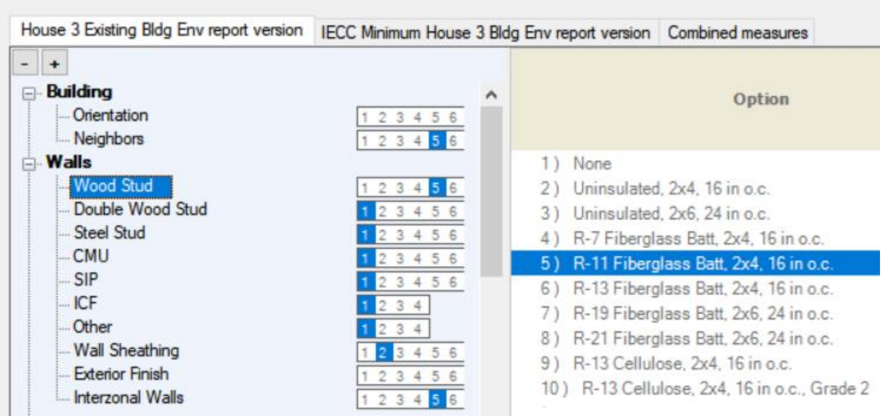
Licensed electrician

Current transducers

Meter

Monitoring

Image Credit: Gentry Kapolei Development, LLC



BEopt simulation menu

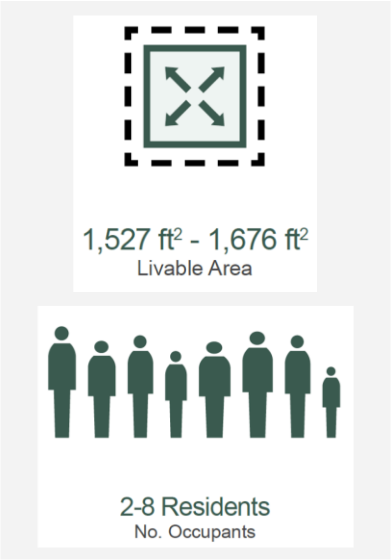
Kanehili Gentry Homes, DHHL, East Kapolei, 2009

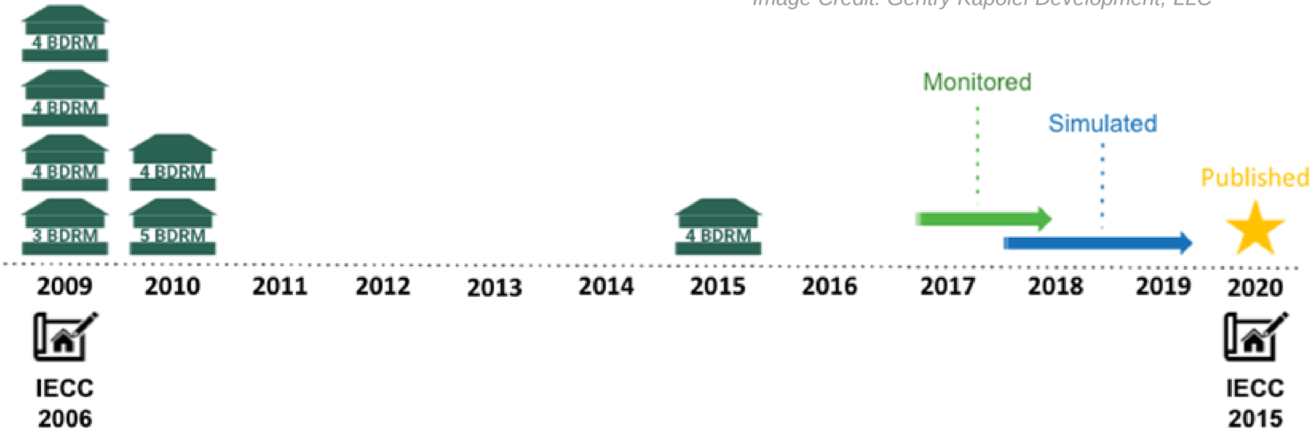
Energy Monitoring and Simulation Study

Peer-reviewed journal article:
Going Beyond Code: Monitoring Disaggregated Energy and Modeling Detached Houses in Hawai‘i by W. Meguro, E. Peppard, S. Meder, J. Maskrey, R. Josephson. *Buildings* 10(7), 120. *Free access.*

Brochure on Hawaii Sea Grant website.

Image Credit: Gentry Kapolei Development, LLC





Kanehili Gentry Homes, DHHL, East Kapolei, 2009

16.1-SEER* central AC, ducts inside conditioned space

Dual pane, low-e glass, vinyl frame, U-value 0.3 and SHGC 0.34

R-11 batt, wood studs

Pre-wired for ceiling fans in living and all bedrooms*

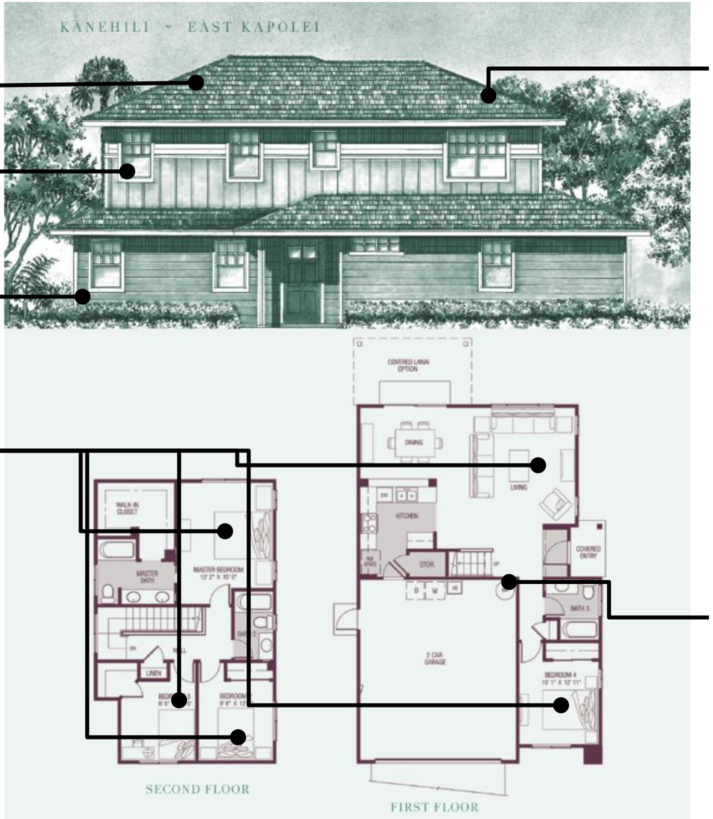


Image Credit: Gentry Kapolei Development, LLC

Open cell spray foam* R-19 insulation at rafters


Image: Courtesy of Peter Stone

Roof-mounted solar water heating panels; electric backup; 120 gal storage

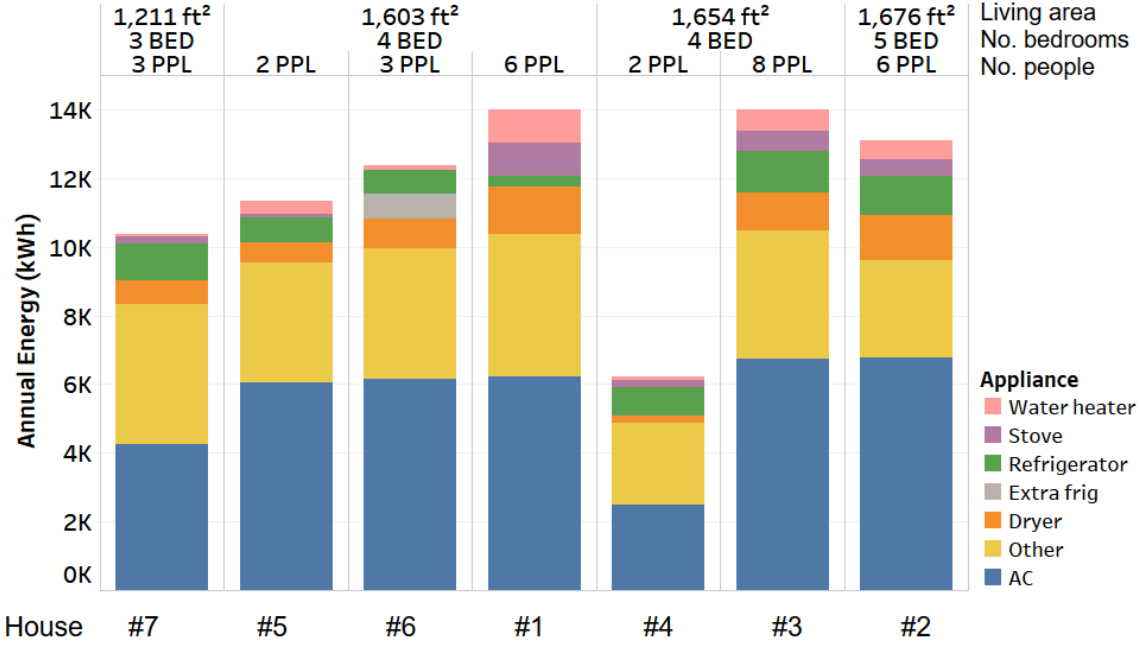
*Beyond code

Kanehili Gentry Homes, East Kapolei, 2009

Image: Gentry Kapolei Development, LLC

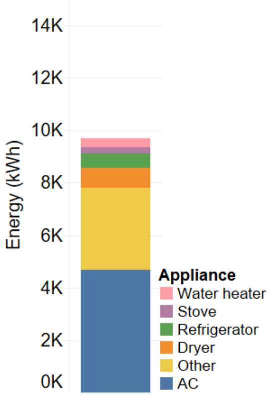
Disaggregated annual energy use

END USE	RANGE (kWh/year)
Water heater	62 - 816
Stove	93 - 985
Refrigerator	714 - 1,203
Dryer	186 - 1,393
Plug loads + lights	2,375 - 4,523
AC	2,455 - 6,816
Whole house use	6,187 - 14,025

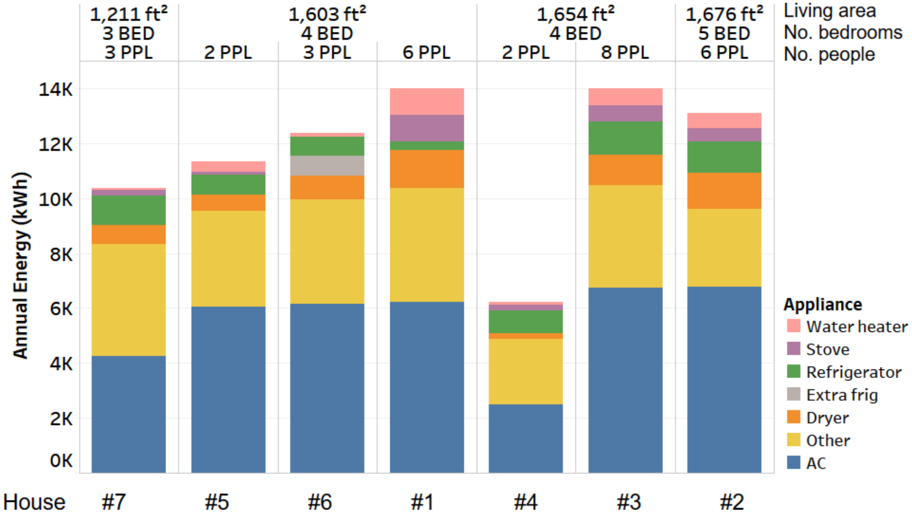


Kanehili Gentry Homes, East Kapolei, 2009

Image: Gentry Kapolei Development, LLC



The State of Hawaii Public Utilities Commission 2020 Market Potential Study. Average annual consumption per household (kWh/HH) in 2018: single family, centrally air conditioned, Oahu (house size unknown). Data adapted by Erik Kolderup.



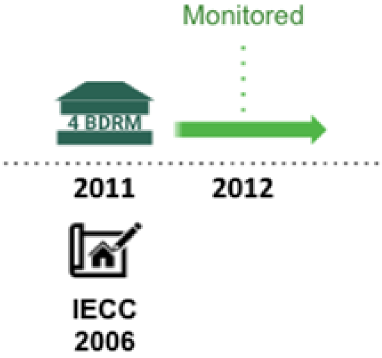
Kanehili measured annual energy consumption 2017-2018.

Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Designed and constructed: Armstrong Builders
Monitored: Hawaii Natural Energy Institute / Sea Grant / Environmental Research and Design lab

2,270 ft^2
Living Area

4 residents



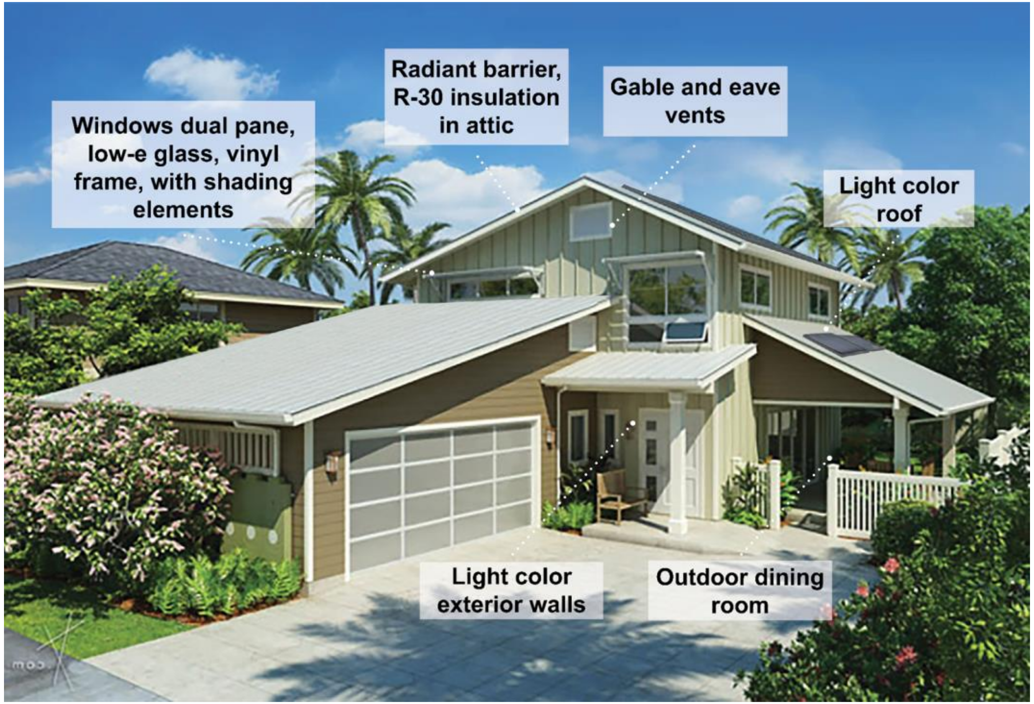
Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aiko Tells
Armstrong Builders | LEED Platinum | NAHB Silver

Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Building Envelope

Radiant barrier under the roof

R-30 batt insulation on attic floor



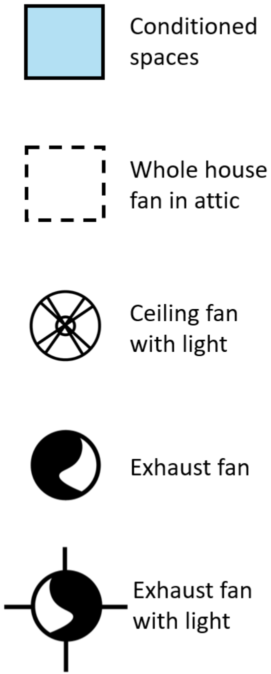
Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aiko Tells

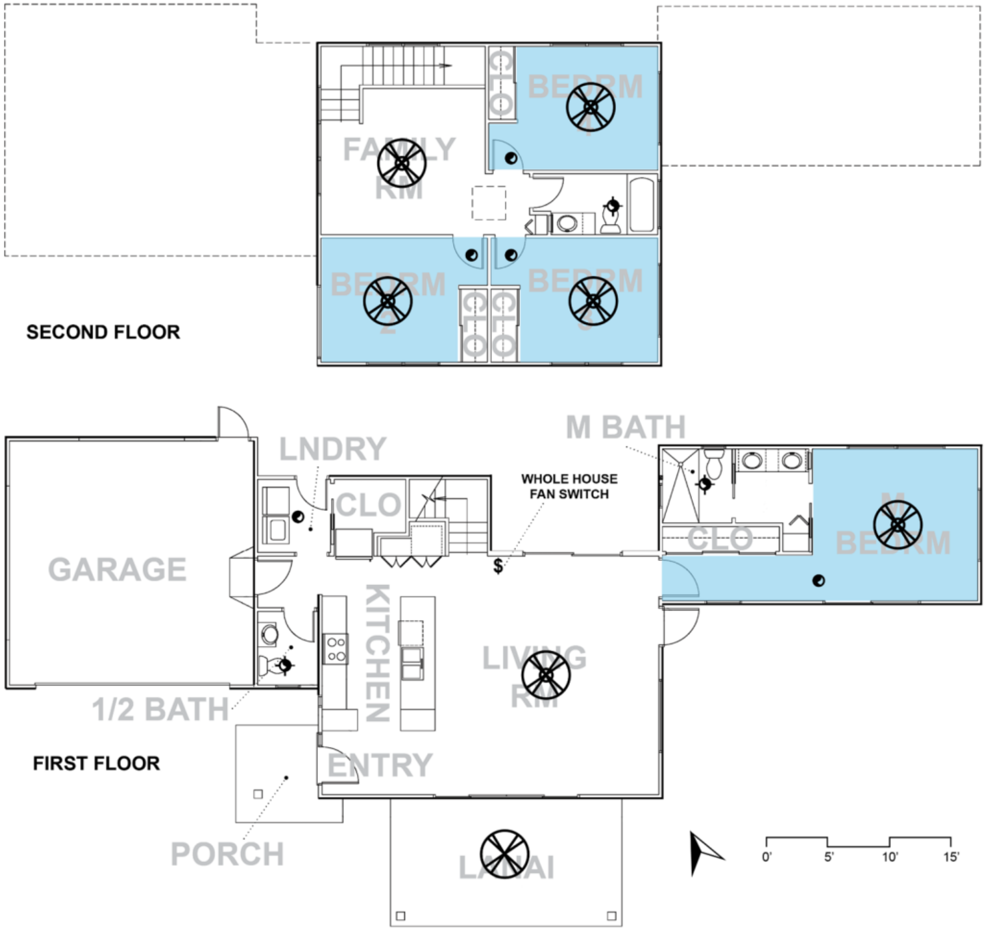
Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Mini-split HVAC, Exhaust Fans, Ceiling Fans, Whole House Fan

Compressors
17,500 BTU SEER 20
30,600 BTU SEER 17.6

Fan coils in each bedroom

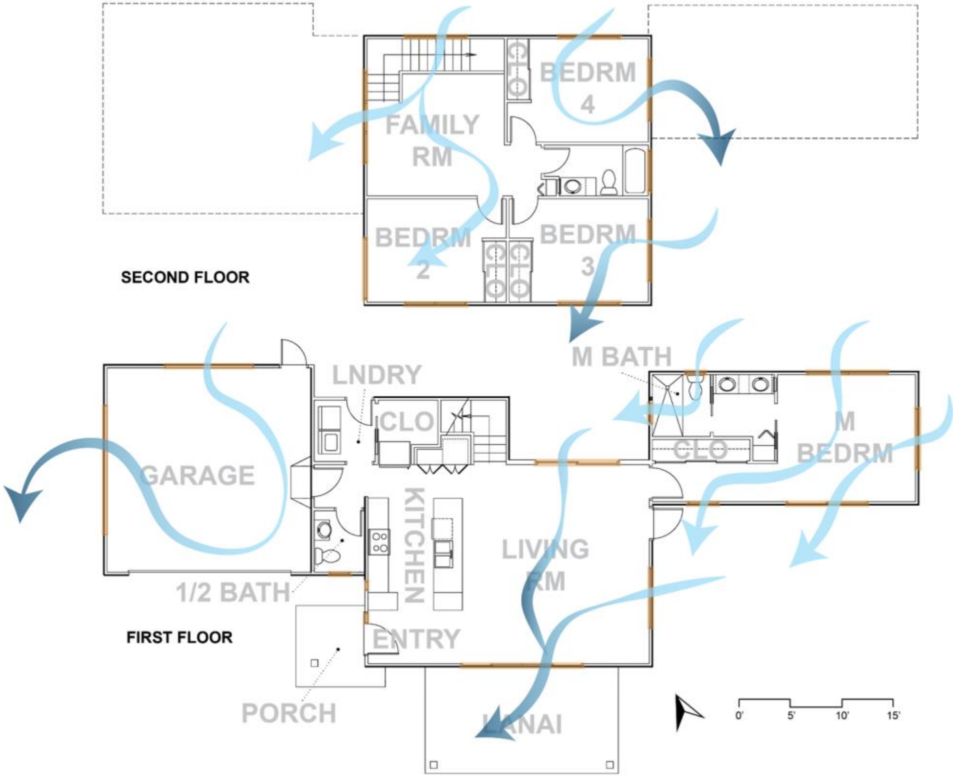




Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Natural Ventilation, Cross Ventilation

Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aikio Tells



Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Natural Daylight

Karen Nakamura, BIA (retired) and James Maskrey, HNEI in the kitchen/living room while the house was on display in 2011.

Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aiko Tells

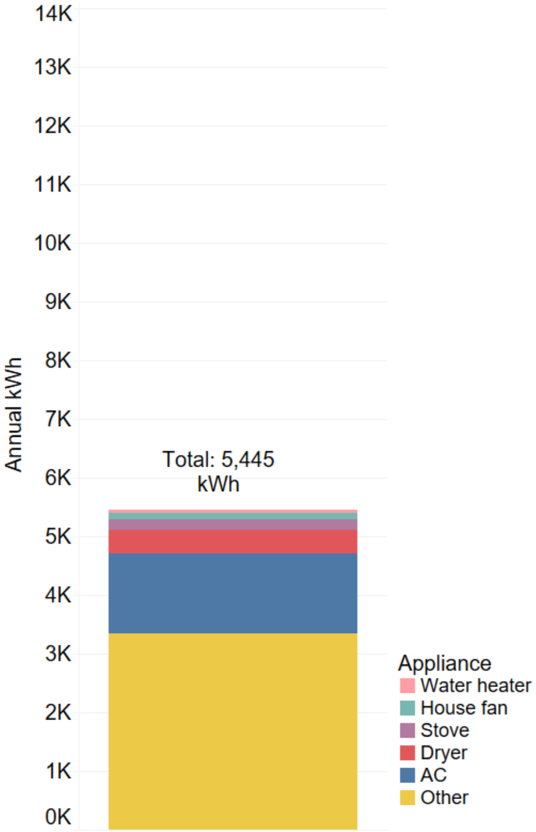
Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Renewable energy

Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aiko Tells

Google Earth accessed 10/25/21

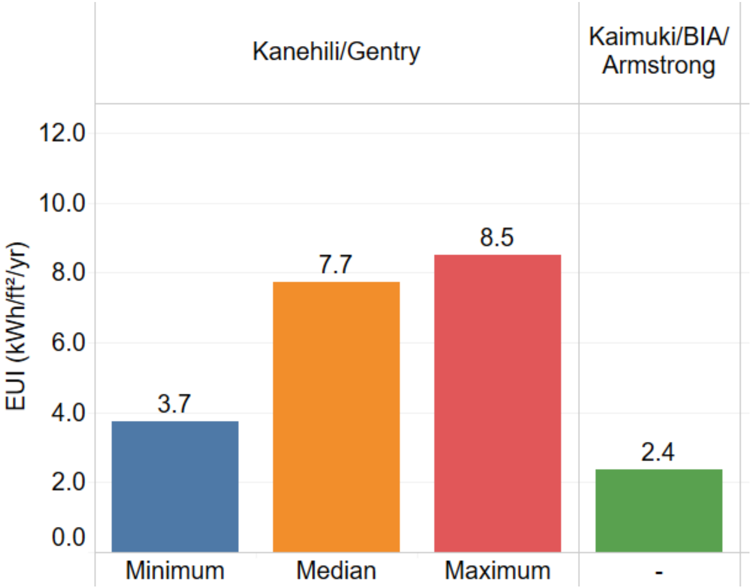
Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki



Rendering by Jeff Brink, Armstrong Builders, edited by Darlyn Chau and Aiko Tells

Building Industry Association (BIA): New Hawaiian Home 2011, Kaimuki

Energy Use Intensity (EUI) Comparison



Energy Use Intensity (EUI):

Calculated by dividing the total energy consumed by the building in one year by the total gross floor area of the building (kWh/ft^2)

A Kaupuni Village Home, Waianae, 2011

Image credit: Group 70

PROJECT PARTNERS
Alcon & Associates
Department of Hawai'ian Home Lands
Group 70 International
Hunt Building Company
Hawai'i Chapter of the U.S. Green Building Council
Hawai'ian Electric Company
University of Hawai'i
U.S. Department of Energy/National Renewable Energy Laboratory
U.S. Department of Housing and Urban Development
Ka'ala Farms
Kamehameha Schools
State of Hawai'i's Department of Business, Economics Development and Tourism

***19 houses total**

3 BDRM
4 BDRM

Monitored

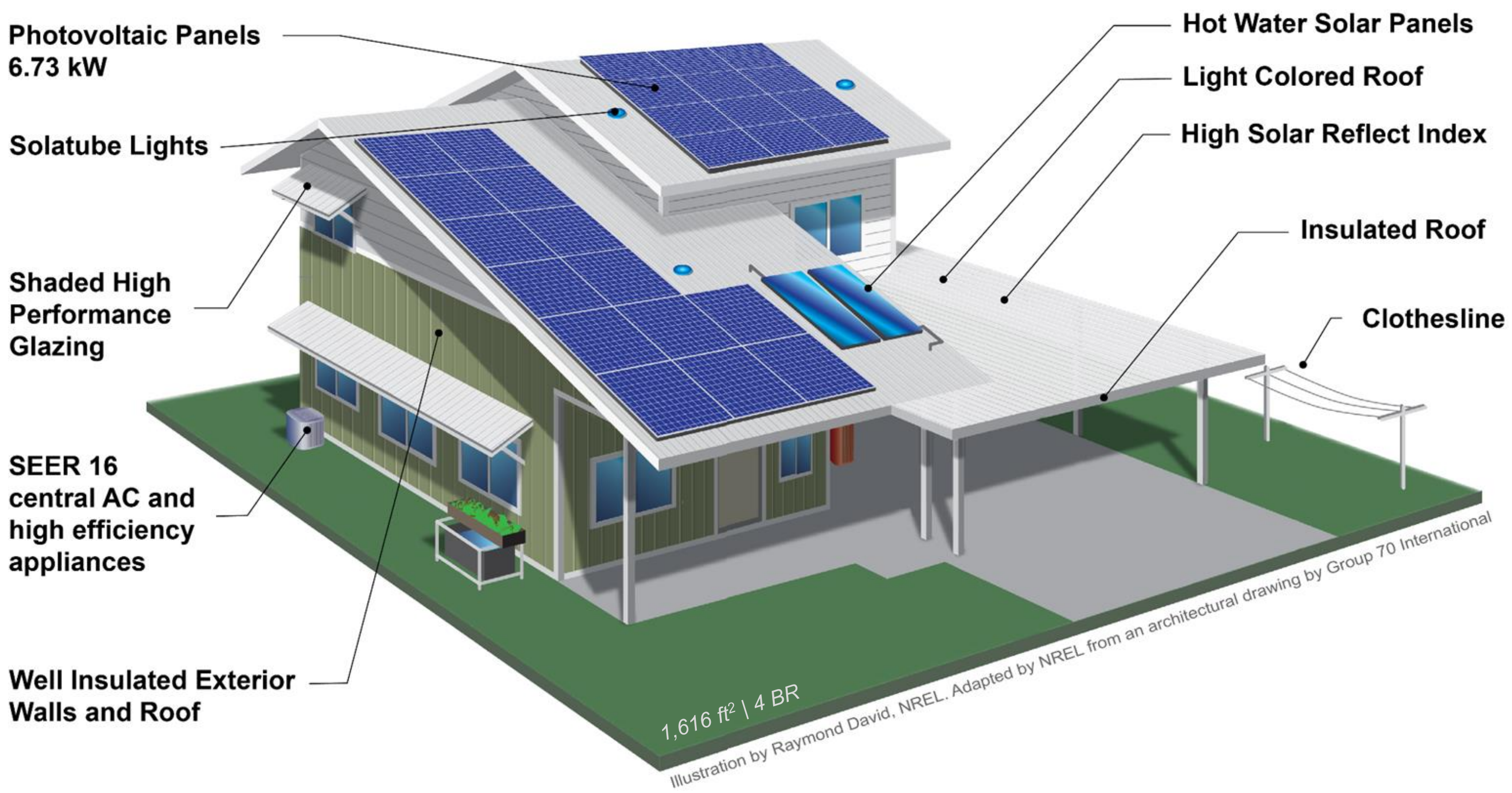
2011
2012

IECC 2006

1,306 - 1,616 ft^2
Living Area

Residents?

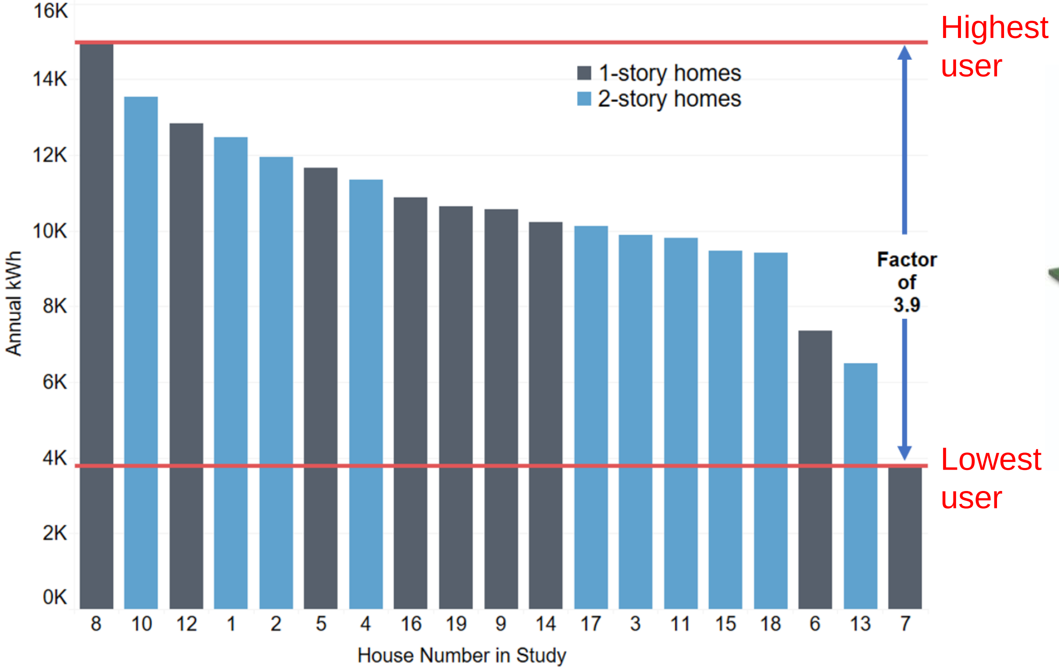
A Kaupuni Village Home, Waianae, 2011



Kaupuni Village: Net Zero Community

Measured performance

First year: performance was within 1% of net zero



Graph adapted by E.Peppard from: Norton, P.; Kiatreungwattana, K.; Kelly, K.J. Evaluation of Model Results and Measured Performance of Net-Zero Energy Homes in Hawai'i. In Proceedings of the 2013 ASHRAE Annual Conference, Denver, CO, USA, 22–26 June 2013.

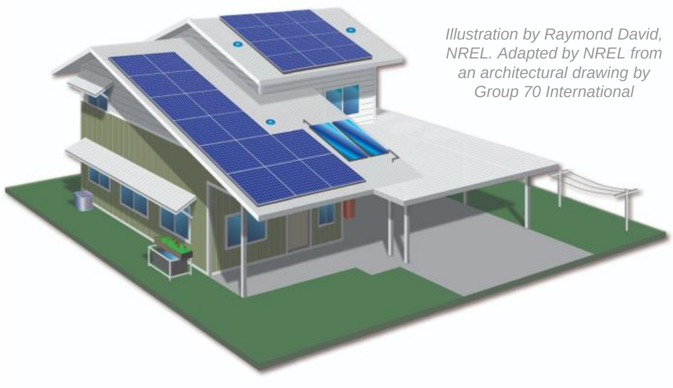


Illustration by Raymond David, NREL. Adapted by NREL from an architectural drawing by Group 70 International

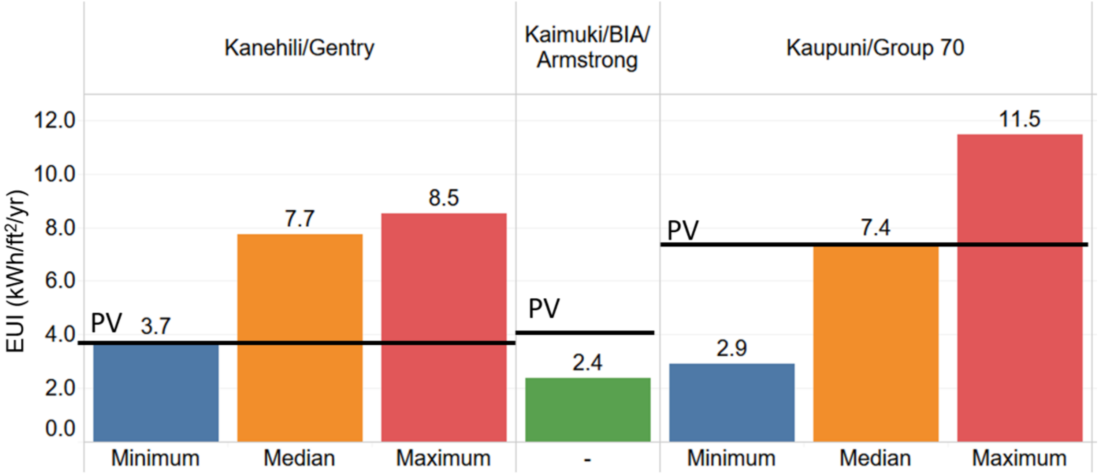
Kaupuni Village: Net Zero Community

Net zero energy results: EUI and PV production

Consumption > Generation

Consumption < Generation

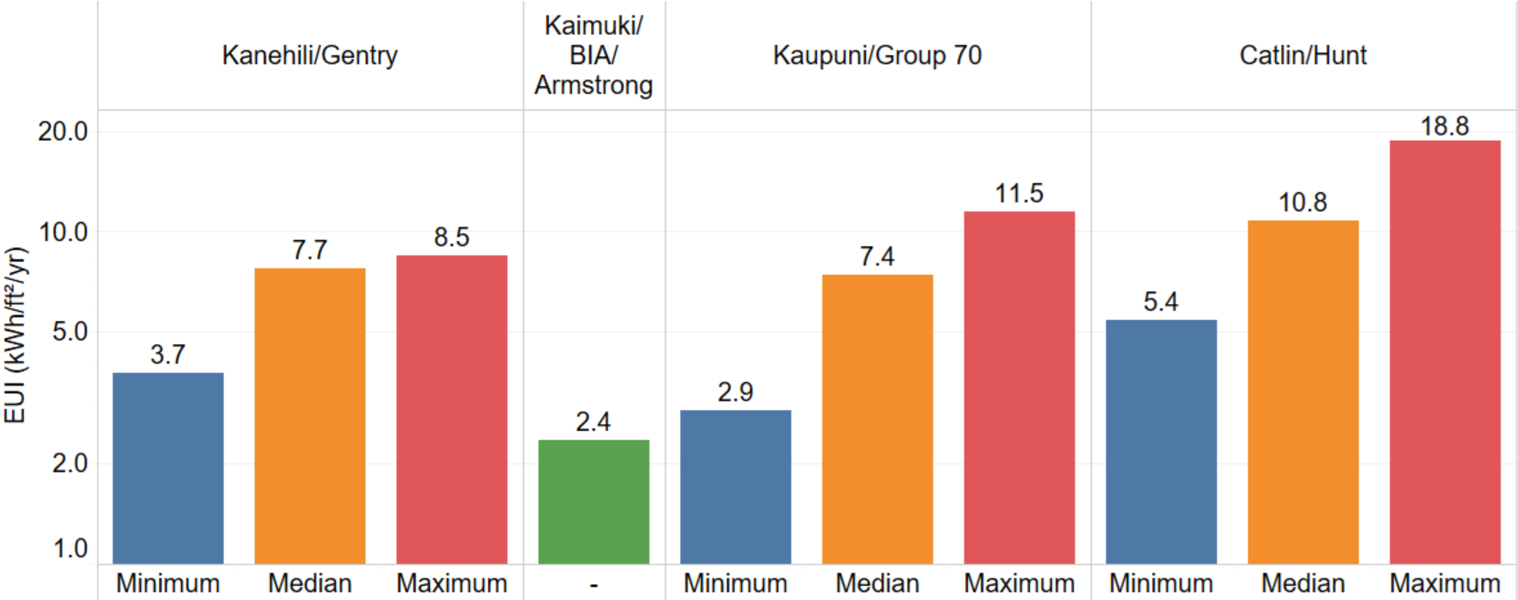
Net zero community



Energy consumption comparisons

Hunt Military Communities' Catlin Neighborhood

- Built 2006-2008
- 319 houses
- 3-4 Bedrooms
- Single family
- Central air
- Data from 2017
- Billing program



Water Heating

Solar, with electric backup

Heat pump

Electric

https://www.energystar.gov/

Water Heating

Heat pump

https://www.energystar.gov/

Efficiency >300%

Cools space

Some noise

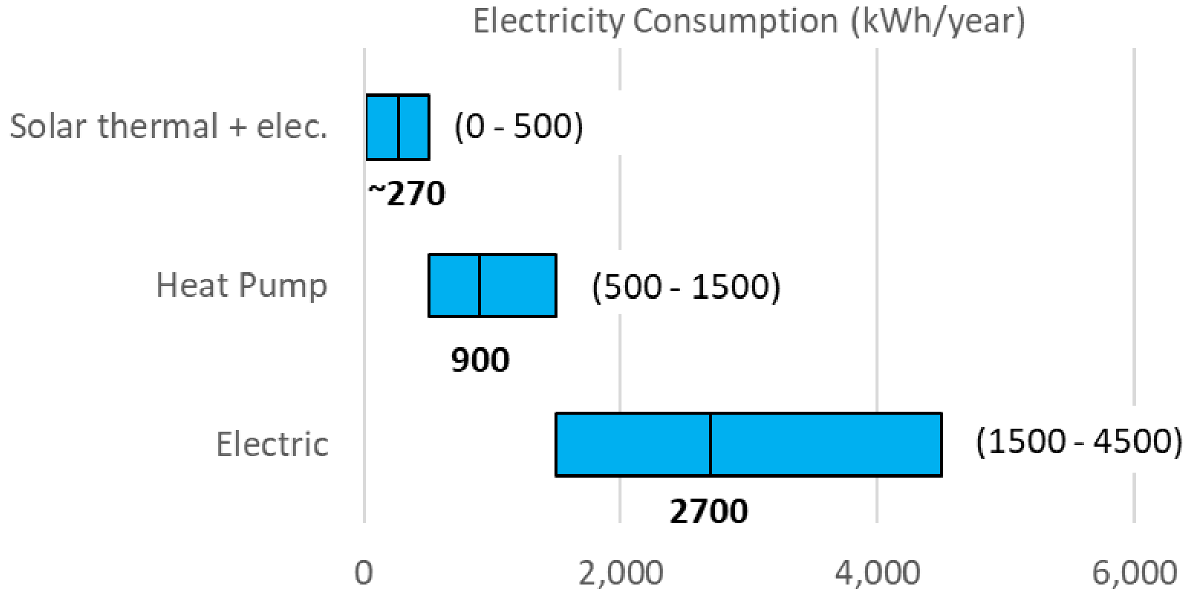
Requires condensate drain

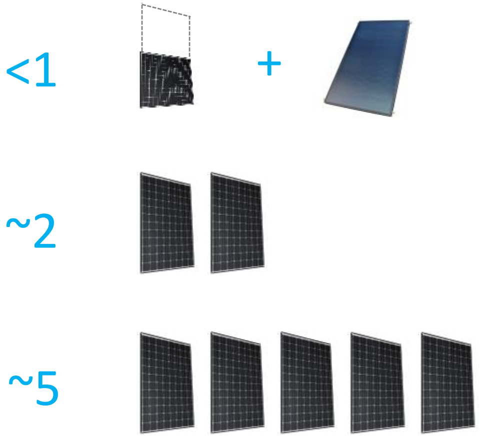
More information

https://hawaiienergy.com/for-homes/water-heating/heat-pump

Water Heating

Number of PV panels





Electric Vehicles

https://www.clippercreek.com

Annual Electricity Consumption (kWh/year)

Considerations

- Miles traveled per year
- Vehicle efficiency
- Fraction of charging at home

Electric Vehicles

https://www.clippercreek.com

Annual Electricity Consumption (kWh/year)

	Vehicle Efficiency (kWh/100 miles)[1]		
	High efficiency	Average efficiency	Low efficiency
	25	33	45
5,000	1,400	1,800	2,500
Hawai'i average miles/year[2] ➡ 9,000	2,500	**3,250**	4,450
15,000	4,150	5,450	7,450

kWh values assume 10% charging loss

[1] https://www.fueleconomy.gov/feg/evsbs.shtml

[2] http://dbedt.hawaii.gov/economic/databook

Electric Vehicles

https://www.clippercreek.com

Number of PV Panels

	Vehicle Efficiency (kWh/100 miles)[1]		
	High efficiency	Average efficiency	Low efficiency
	25	33	45
5,000	2.8	3.6	5.0
9,000	5.0	6.5	8.9
15,000	8.3	10.9	14.9

Hawai'i average miles/year[2] ➡ 9,000

Assumes 10% charging loss
500 kWh/yr per PV panel

[1] https://www.fueleconomy.gov/feg/evsbs.shtml

[2] http://dbedt.hawaii.gov/economic/databook

How Hawai'i Homes Use Energy - Summary

Major factors

- Comfort strategy and type of AC system
- Type of water heating system
- Occupant behavior
- Appliance selection
- Electric vehicle charging

The energy code,
the starting point for efficiency

Energy code requirements

2018 IECC with Hawaii amendments

Envelope

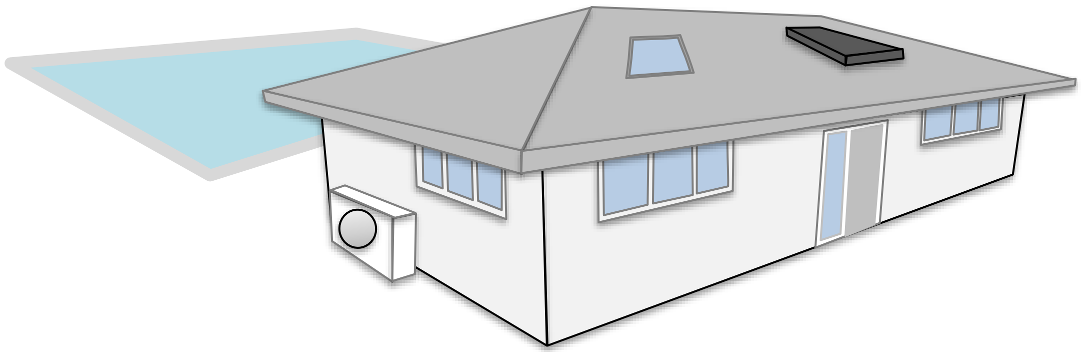
Roof
Walls
Windows & skylights
Air leakage

Systems

Air conditioning controls
Duct insulation
Duct leakage
Water heating
Swimming pool

Electrical

Permanently installed lighting
Ceiling fan
~~EV readiness~~
~~PV readiness~~
} Up to counties for 2018



Not covered

AC efficiency
Water heater efficiency
Plug-in lighting
Appliances

Tropical zone option

If ≤ 50% AC

Energy code requirements

2018 IECC with Hawaii amendments

Low-rise residences

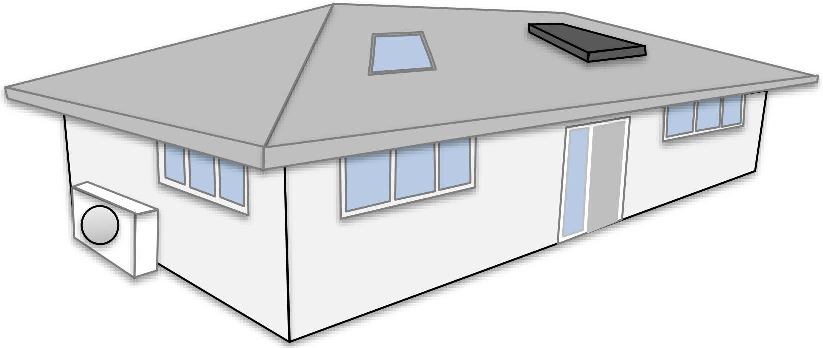
With air conditioning

Skylights
SHGC ≤ 0.30
U-factor ≤ 0.75

Water heating
Solar*

Roof
R-30*

AC efficiency
SEER ≥ 14
(Federal standard)



Walls
Wood: R-13
Metal: R-13 +R-4.2*

Windows
SHGC ≤ 0.25

High efficacy lighting

Ceiling fan wiring

Where are beyond code savings available?

* Some exceptions

Energy code requirements

PRESCRIPTIVE REQUIREMENTS CHECKLIST

Component/System	Requirement	Code Section	Plan Review Notes	Info on Plans
Roof – wood frame	☐ **R-30**, ☐ **U-0.035**, ☐ Total UA alternative, or ☐ Points option	R402.1, R402.1.5, R407*	Some R-30 options: • 10 in. batt insulation • 5 to 8 in. spray foam	☐ Insulation location on plans ☐ Insulation R-value on plans
Roof – metal truss	☐ **R-38**, ☐ **U-0.035**, ☐ **R-30** + **R-3**, ☐ **R-26** + **R-5**, ☐ *Total UA alternative*, or ☐ *Points option*	R402.1, R402.2, R402.1.5, R407*	Metal frame creates a thermal bridge, and more insulation is required. "R-3" and R-5" refer to continuous insulation, typically foam board.	☐ Insulation location on plans ☐ Insulation R-value on plans
Roof – metal joist	☐ **R-38** in 2x4, 2x6 or 2x8 framing, ☐ **R-49** in any framing ☐ *Total UA alternative*, or ☐ *Points option*	R402.1, R402.2, R402.1.5, R407*		☐ Insulation location on plans ☐ Insulation R-value on plans
Wall – wood frame	☐ **R-13**, ☐ **U-0.084**, ☐ *Total UA alternative*, or ☐ *Points option*	R402.1, R402.1.5, R407*	Some R-13 options: • 3.5 in. batt insulation • 2 to 3.5 in. spray foam	☐ Insulation location on plans ☐ Insulation R-value on plans
Wall – metal frame	Framing 16 in. on center: ☐ **R-13** + **R-4.2** ☐ **R-21** + **R-2.8** Framing 24 in. on center: ☐ **R-13** + **R-3.0** ☐ **R-15** + **R-2.4** ☐ *Total UA alternative*, or ☐ *Points option*	R402.1, R402.2, R402.1.5, R407*	Requires insulation in framing cavity plus a layer of continuous insulation (typically foam board).	☐ Insulation location on plans ☐ Insulation R-value on plans
Wall – mass (CMU or concrete)	☐ **R-3** exterior, ☐ **R-4** interior, ☐ **U-0.197**, ☐ Exterior reflectance ≥**0.64**, ☐ Overhang projection factor ≥**0.3**, ☐ Mass wall thickness ≥ **6** inches, ☐ *Total UA alternative*, or ☐ *Points option*	R402.1*	Requires either exterior or interior insulation, typically foam board. CMU integral insulation does not comply. Hawaii amendments add several alternatives .	☐ Insulation location on plans ☐ Insulation R-value on plans

https://energy.hawaii.gov/hawaii-energy-building-code/building-code-resources

Beyond-code efficiency strategies

Simulation of energy efficiency measures beyond IECC 2015

Image: Gentry Kapolei Development, LLC

Estimate energy savings

~45-47% annual energy savings possible beyond IECC 2015

BEopt software
EnergyPlus

Discuss with developers & builders

Prioritize and market measures

Inform new construction

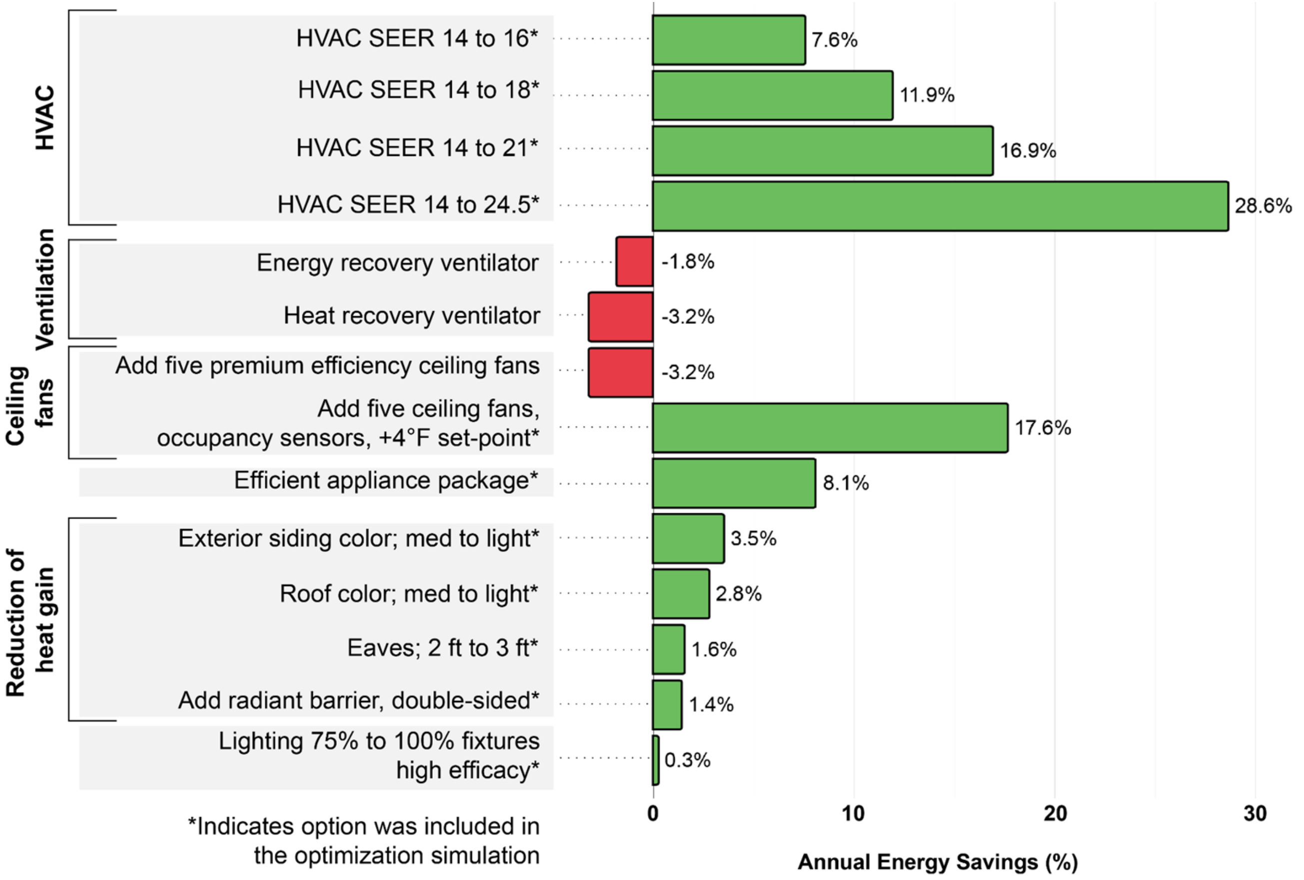
Requests for Proposals

Share with building professionals

Peer-reviewed journal paper, brochure, conferences

https://doi.org/10.3390/buildings10070120

Simulation of energy efficiency measures



*Indicates option was included in the optimization simulation

Image: Gentry Kapolei Development, LLC

Parametric Analysis

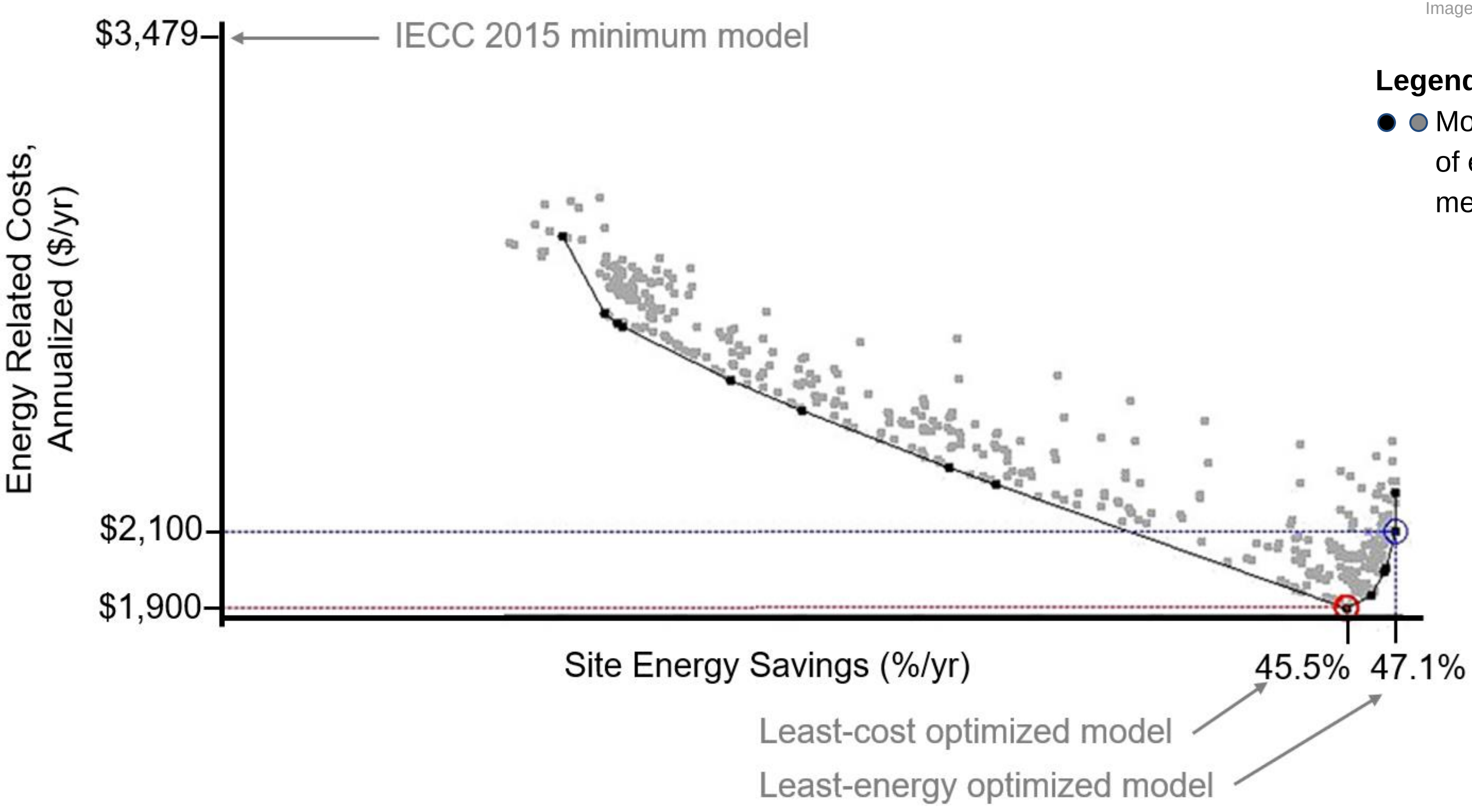
Base Case based on Gentry 4-bedroom, 1,654 ft^2 house modified to be minimally compliant to IECC 2015 energy code.

Percent savings represents the change of one efficiency measure at a time.

https://doi.org/10.3390/buildings10070120

Optimization simulation
Energy related costs vs. energy savings

Image: Gentry Kapolei Development, LLC



Legend

● ● Modeled combinations of energy efficiency measures

Image: BEopt output graph, adapted

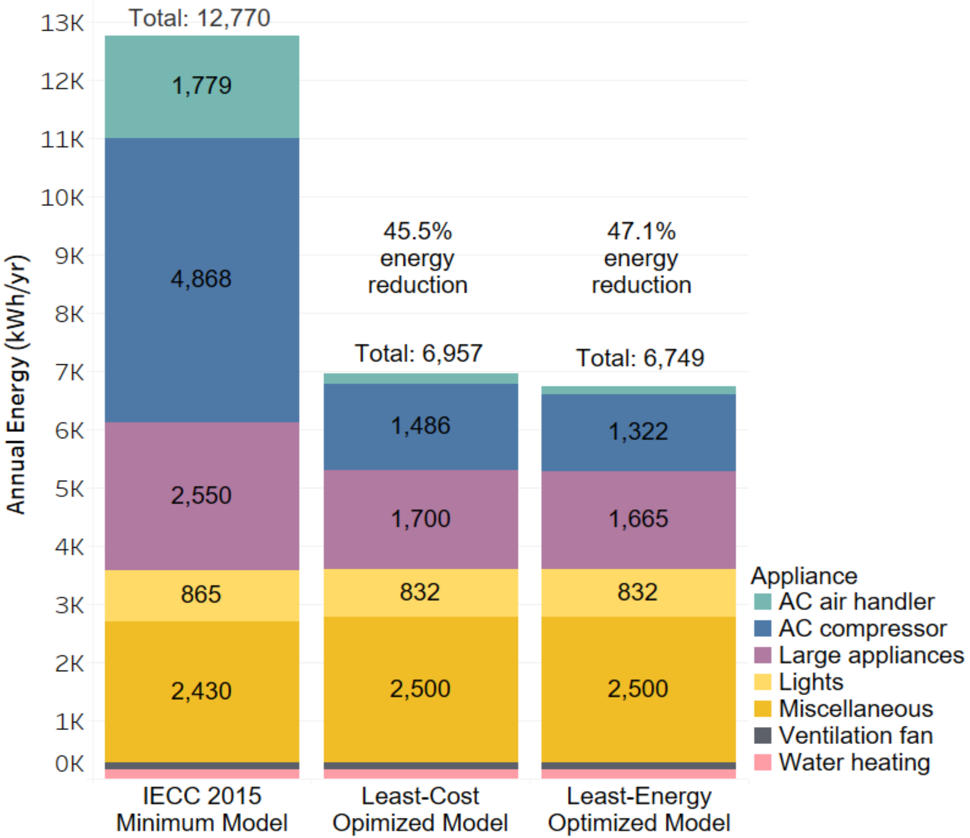
https://doi.org/10.3390/buildings10070120

Optimization Model Differences

Category	Variable	IECC 2015 Minimum Baseline Model	Least-Cost Optimized Model	Energy-Optimized Model
HVAC	Seasonal Energy Efficiency Ratio (SEER) for central AC	14	Variable speed SEER 24.5	Variable speed SEER 24.5
	Cooling set-point (°F)	75	79	79
	Ceiling fans	No ceiling fans	Five premium efficiency fans; occupancy sensors;	Five premium efficiency fans; occupancy sensors;
Equipment	Appliances	Standard efficiency	Energy efficient, except stove is standard electric	Energy efficient including induction stove
Envelope	Exterior finish color	Medium	Light	Light
	Eaves length (ft)	2	2	3
	Radiant barrier	None	Double-sided foil radiant barrier	Double-sided foil radiant barrier
	Roof material	Medium color asphalt shingle. Absorptivity: 0.75	Medium color asphalt shingle. Absorptivity: 0.75	White metal roof. Absorptivity: 0.30
	Window U-value (Btu/h-ft^2-°F)	0.5	0.4	0.5
Lighting	Lighting	75% high efficiency lighting	100% LED lighting	100% LED lighting

Optimization simulation
Annual Energy Use

Image: Gentry Kapolei Development, LLC

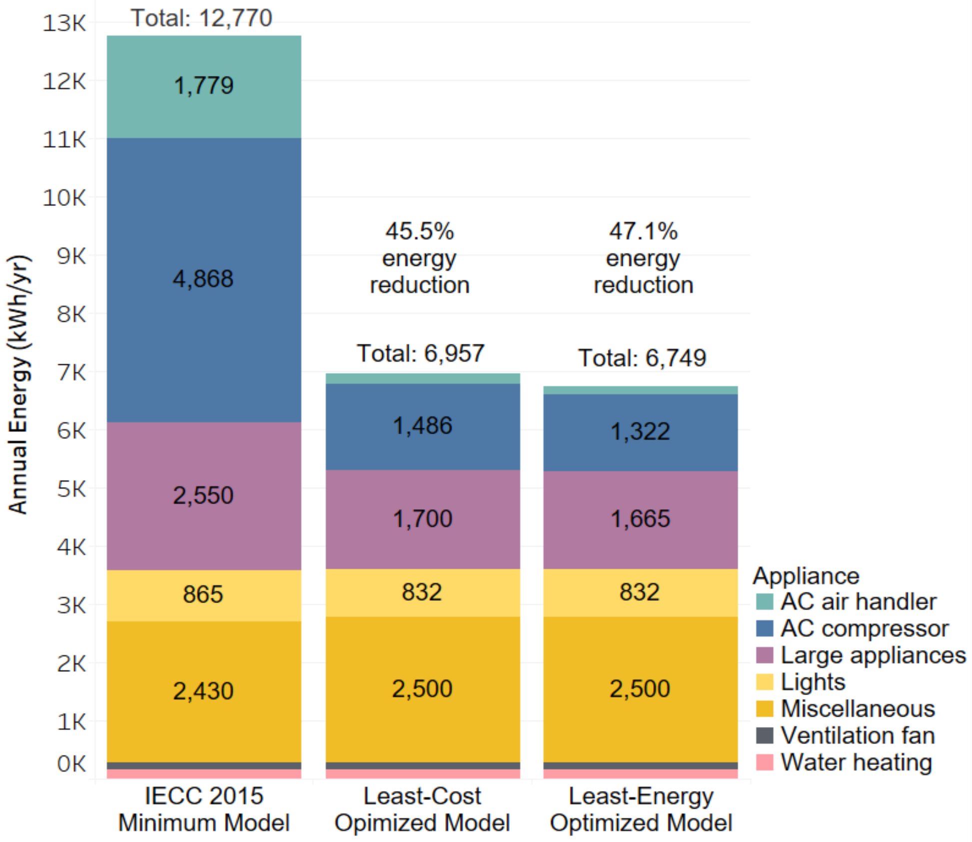


https://doi.org/10.3390/buildings10070120

Optimization simulation
Annual Energy Use

https://doi.org/10.3390/buildings10070120

Image: Gentry Kapolei Development, LLC

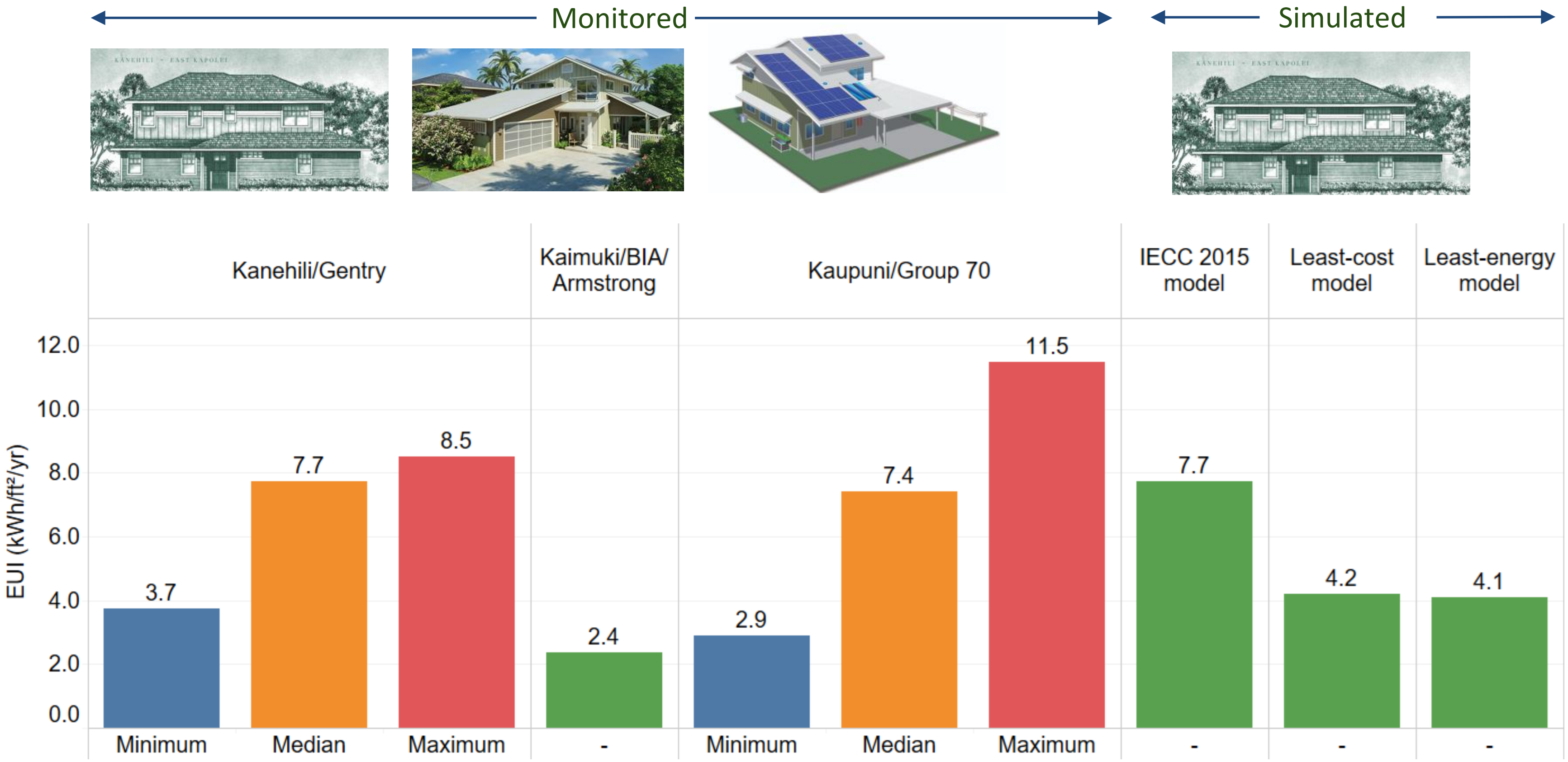


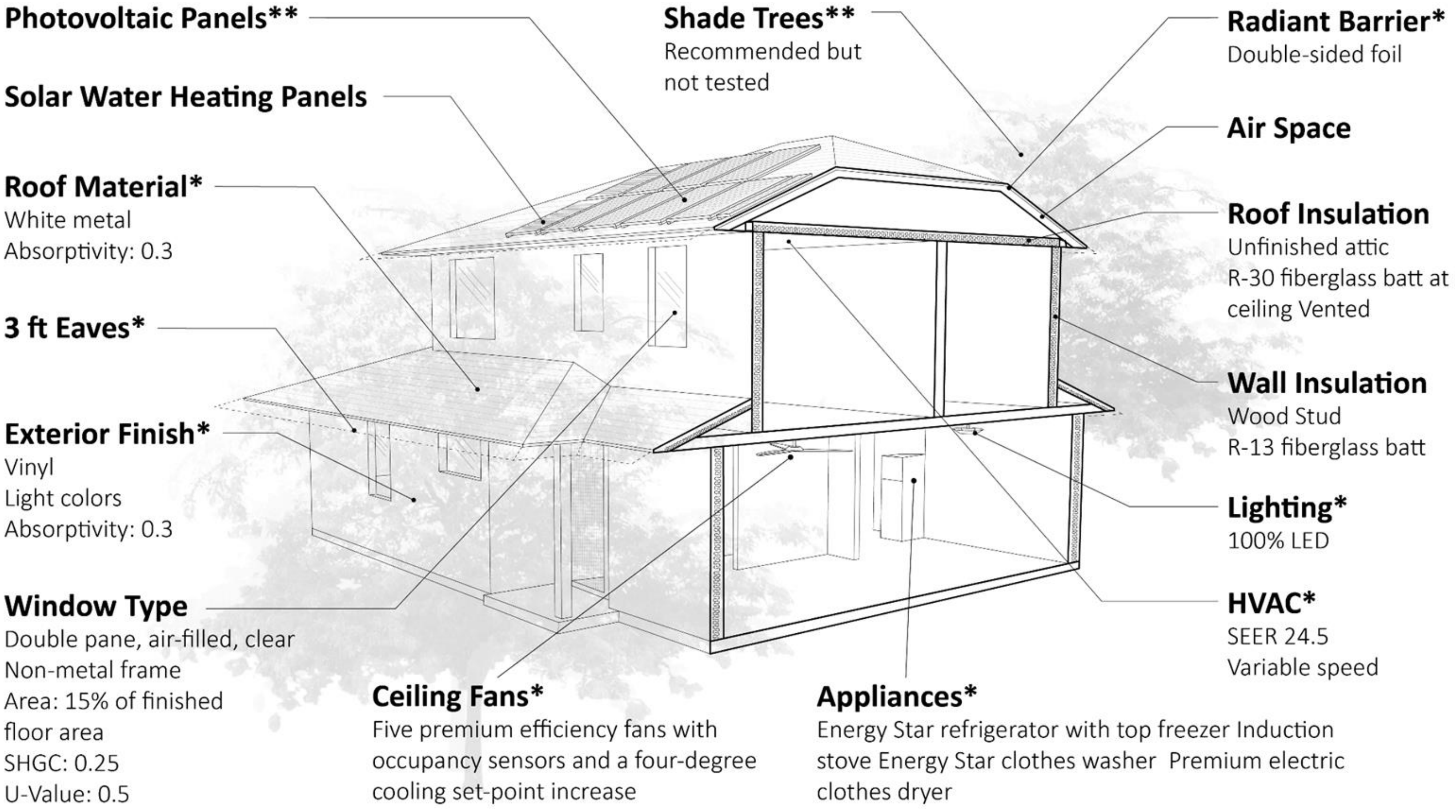
saves ~$1300 in energy-related costs annually per house

saves ~ 15 metric tons CO_2e annually per house

If applied to all Oahu new residential for 5 years (~5,300 houses), saves ~ 79,000 metric tons CO_2e and over $7 million in energy bills.

Simulation addition to Energy Use Intensity (EUI) Comparison





The energy-optimized model is depicted. Items with * were modified from the IECC 2015 minimum. Items with ** were not modeled but are recommended.

https://doi.org/10.3390/buildings10070120

Additional Resources

Heat Pump Water Heater Resources

Hawaii Energy Info
https://hawaiienergy.com/for-homes/water-heating/heat-pump

Advanced Water Heating Initiative (NBI)
https://www.advancedwaterheatinginitiative.org/

Key Product Criteria (DOE)
https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria

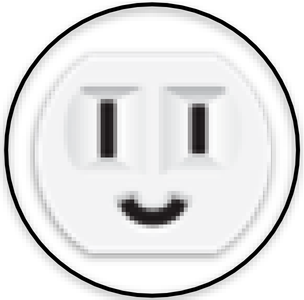
Product Lists and Criteria

Energy Star Induction Stoves
https://www.energystar.gov/about/2021_residential_induction_cooking_tops

Energy Star Heat Pump Dryer
https://www.energystar.gov/products/heat_pump_dryer

Consortium for Energy Efficiency Product List
https://cee1.org/content/cee-program-resources

BuildingGreen Products
https://www.buildinggreen.com



Residential Rebates: Hawaii Energy

Air conditioning tune-up
Mini split systems
Window unit upgrade
Whole house fan
Attic solar fan
Heat pump water heater
Solar thermal
Appliances
Lighting
Pool pump

https://hawaiienergy.com/for-homes/rebates

Additional Resources

All-electric retrofit

Guide for Residential Retrofits
by Redwood Energy

https://redwoodenergy.net/wp-content/uploads/2021/02/Pocket-Guide-to-All-Electric-Retrofits-of-Single-Family-Homes.pdf#page=9

Building Decarbonization Code Overlay

Renewable energy infrastructure
Electric vehicle infrastructure
Energy storage infrastructure
Demand response thermostats
Demand response water heating
AC & water heating efficiency
Tropical Code

https://newbuildings.org/resource/building-decarbonization-code/

Acknowledgements

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Mahalo to volunteer homeowners, Gentry Homes, Armstrong Builders, BIA, National Renewable Energy Lab

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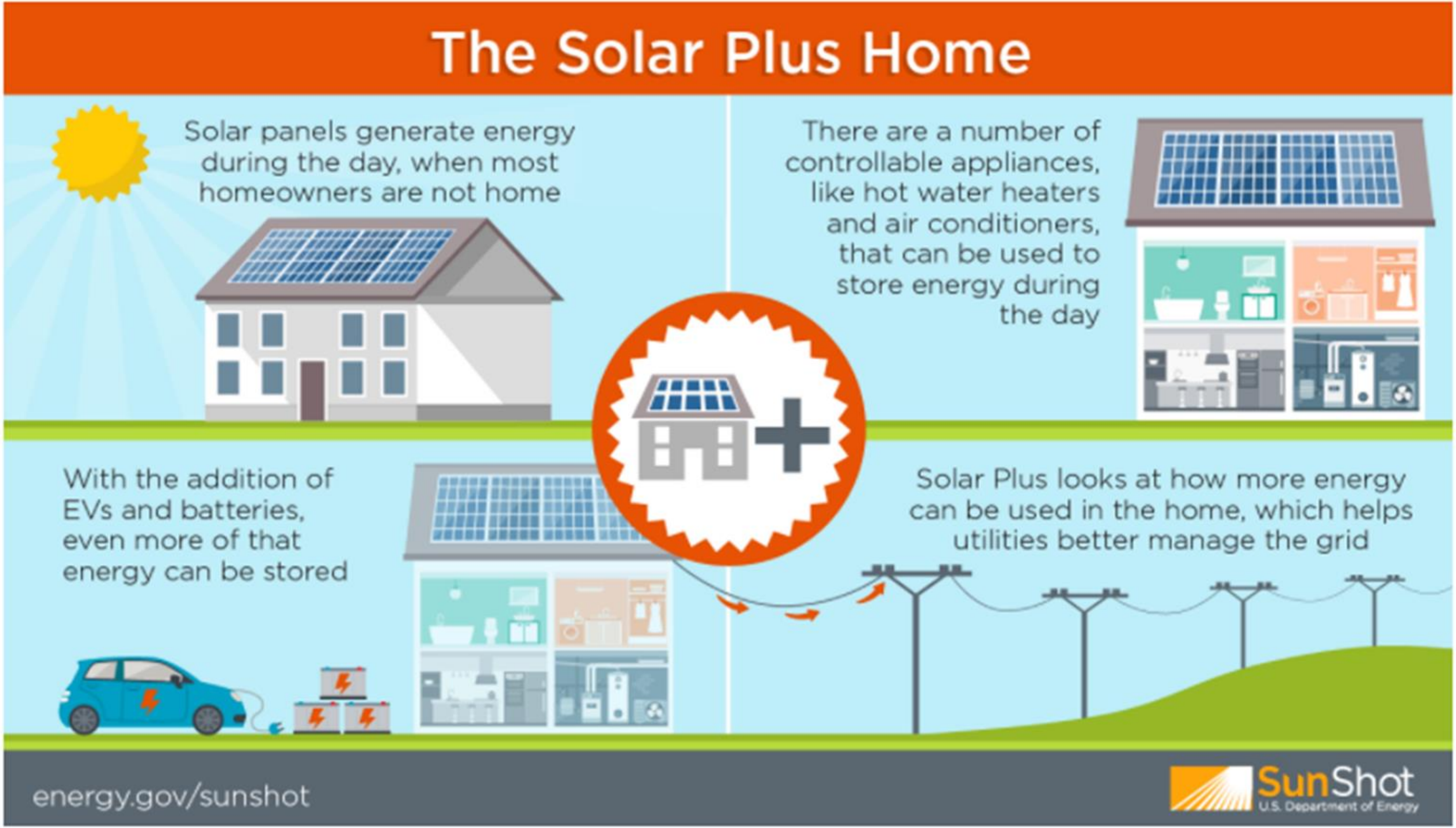
Riley Josephson	Dustin Chang	Trevor Alexander
Kathryn Paradis	Shane Matsunaga	Jason Epperson
Aarthi Padmanabhan	Ben Thrun	Aiko Tells
Carlos Paradis	Branden Annino	Darlyn Chau

Integrating PV and batteries

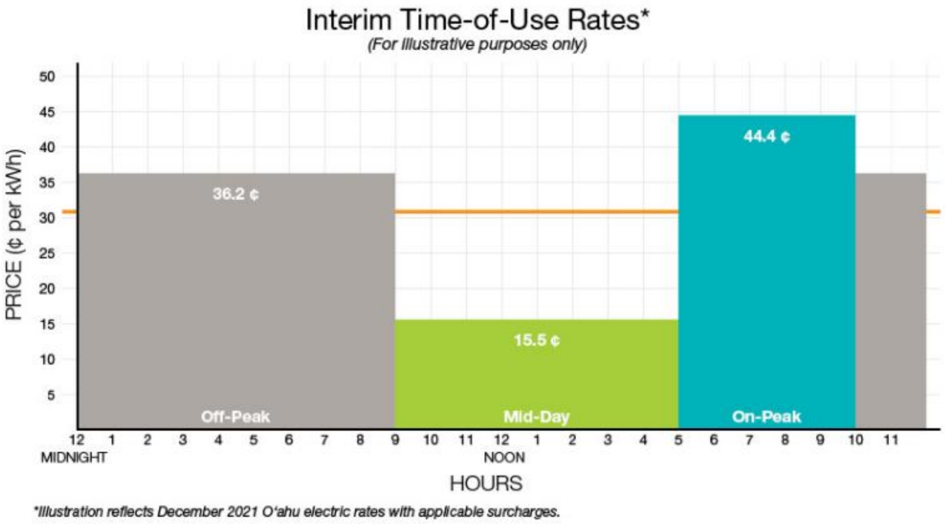

The Solar Plus Home
Solar panels generate energy during the day, when most homeowners are not home
There are a number of controllable appliances, like hot water heaters and air conditioners, that can be used to store energy during the day
With the addition of EVs and batteries, even more of that energy can be stored
Solar Plus looks at how more energy can be used in the home, which helps utilities better manage the grid
energy.gov/sunshot
SunShot
U.S. Department of Energy

Understanding utility tariff structures is key

OAHU	CGS	CGS Plus	CSS	Smart Export
Export Allowed	Yes	Yes	No	Yes
Export Restrictions	No	No	N/A	Solar Day
Reconciliation	Monthly	Annual	N/A	Annual
Minimum Bill	$25	$25	$25	$25
Credit rate (c/kWh)* **	$0.15	$0.10	N/A	$0.15
Program Cap	51.3 MW	50 MW	N/A	25 MW
Inverter Requirements	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.*	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.
Controls	N/A	Yes: Utility or Aggregator	Customer	Yes: Economic
Communications	N/A	N/A	Yes	N/A

- https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/private-rooftop-solar

Time of Use rates enhance value of PV plus Battery

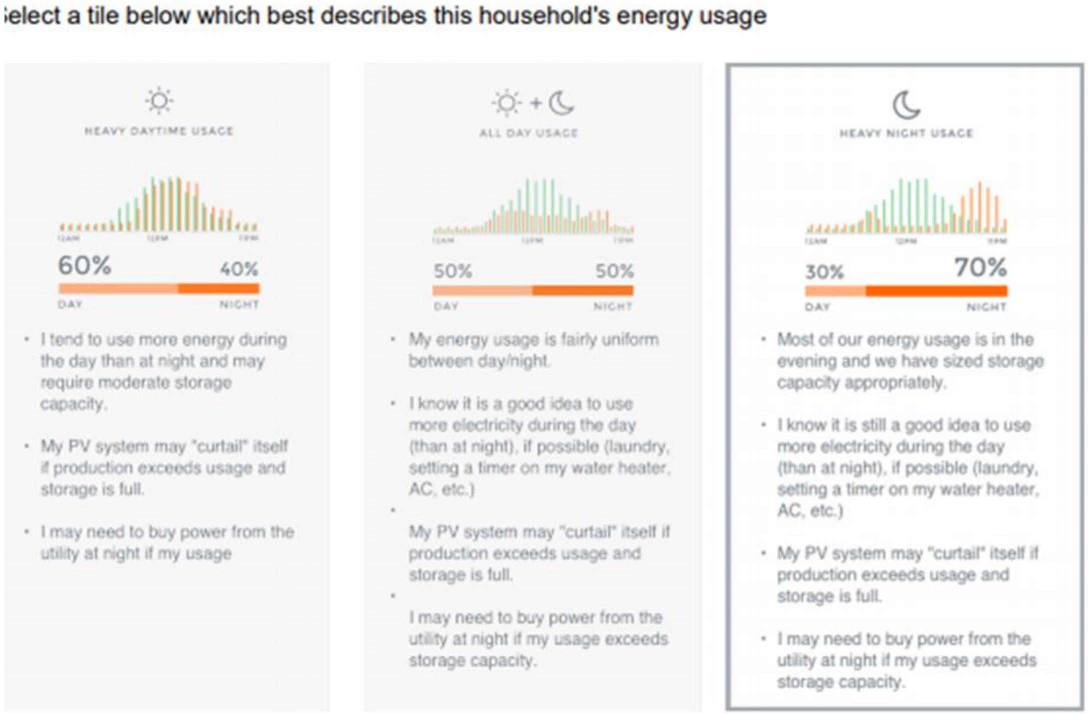


NON-FUEL ENERGY CHARGES - ¢ per kWh:

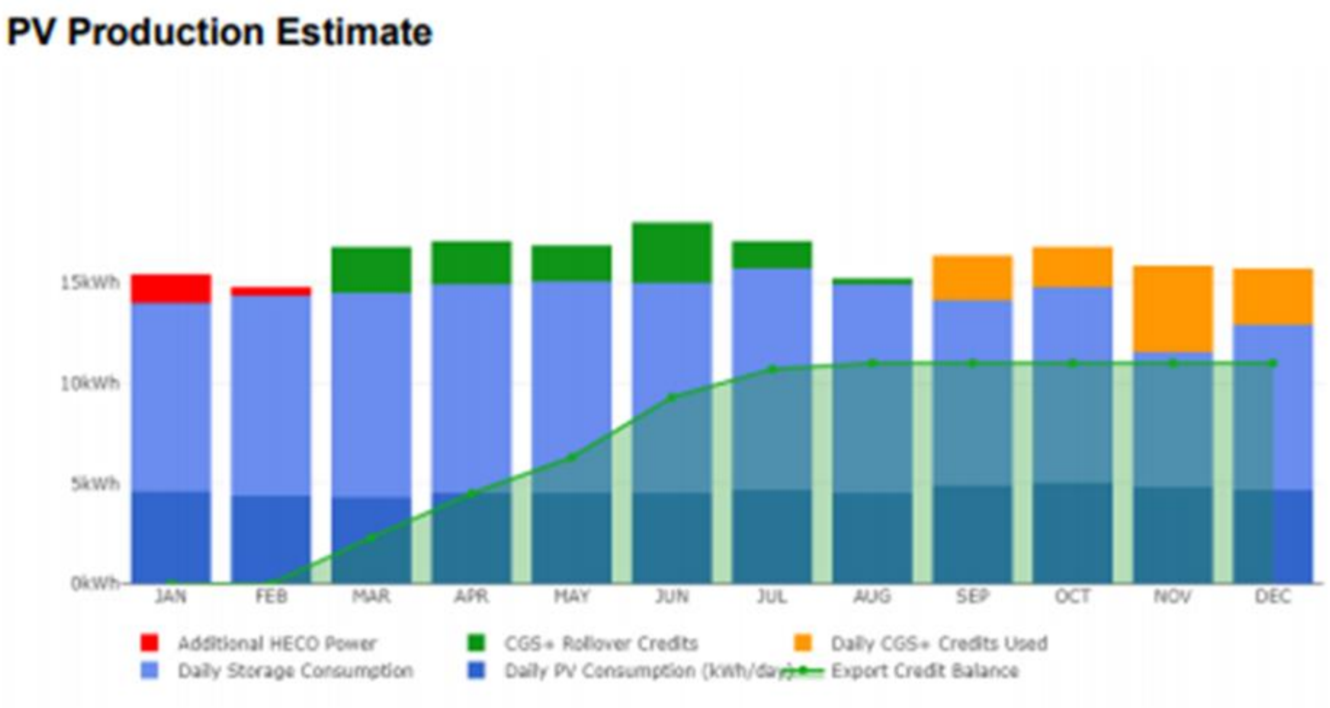
TIME-OF-USE CHARGES

On-Peak Period - per kWh	24.4084 ¢/kWh
Mid-Day Period - per kWh	-4.5493 ¢/kWh
Off-Peak Period - per kWh	16.1367 ¢/kWh

Solar Economics 101 - Optimizing Design



Solar Economics 101 - Optimizing Design



Solar Economics 101 - Investment Payback

PV Project Investment Summary

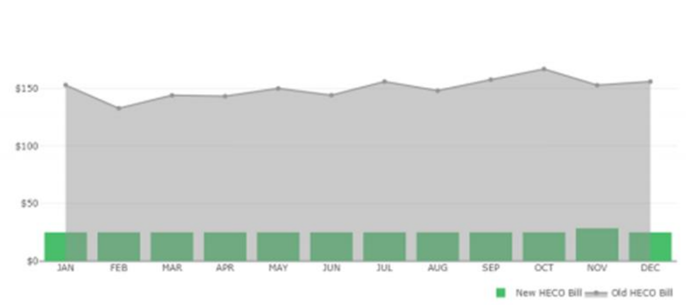
Subtotal $ 27,300.18
Default Hawaii GET $ 1,286.38
Gross System Cost $ 28,586.56
Federal ITC $ 8,575.97
State REITC $ 5,000.00
(or) State refundable REITC $ 3,500.00
Net System Cost $ 15,010.59

Method of Payment: Discount Pay By Check

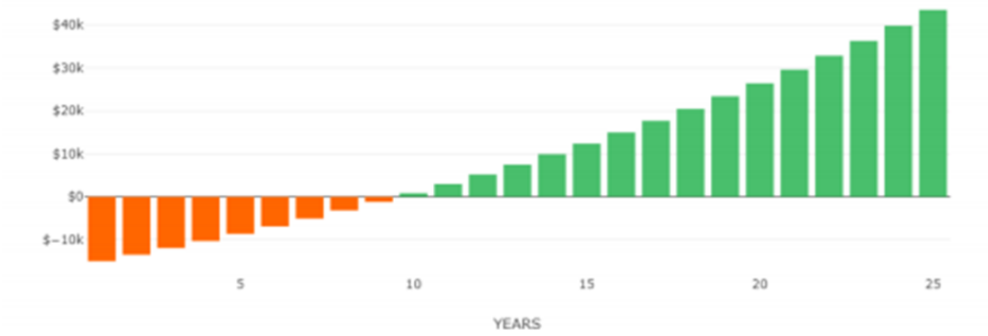
First Year Savings Estimate

Average Old Monthly HECO: $ 150.17
Est. Avg New Monthly HECO: $ 25.30
Est. First Year Savings: $ 1,498.51

HECO Bill Comparison (Estimated)



25 Year Estimated Savings



The F-150 Lightning is coming...

….and it's a big battery on wheels

FORD F-150 LIGHTNING
CHARGING OPTIONS AND ESTIMATED CHARGE TIMES

Estimated charge times 15% to 100% at 240 volts[1]

				
	Ford Mobile Charger 32-amp	**Ford Connected Charge Station** 48-amp	**Ford Charge Station Pro** 80-amp	**Electrify America DC Fast Charging Station** 150-kW (15% to 80% charge)
Standard-Range Battery (targeted EPA-estimated range of 230 miles[2])	**14 hours***	**10 hours**	**10 hours**	**44 minutes**
Extended-Range Battery (targeted EPA-estimated range of 300 miles[3])	**19 hours***	**13 hours**	**8 hours**	**41 minutes**
	32-amp portable AC charger runs on either a 120- or 240-volt AC wall outlet and is included in the purchase or lease of an F-150 Lightning.	48-amp wall mount AC charger runs on a wired 240-volt AC circuit for faster Level 2 home, office or depot charging than the basic 32-amp Ford Mobile Charger.	80-amp wall mount AC charger runs on a wired 240-volt AC circuit for optimal AC charging capability. On the extended-range F-150 Lightning, it works with the truck's dual on-board chargers for 15% to 100% overnight charging in about 8 hours.	Up to 150 kW for rapid charging on the road, the F-150 Lightning can access network of DC fast chargers that can add up to 41 miles of range in about 10 minutes on the standard range truck and up to 54 miles of range in about 10 minutes on the extended range truck.[4]

*Charge time shown with 240-volt power connetion.

PV and EV-readiness for new homes

- Energy Code Section R404.2 Solar conduit and electric panel readiness
  - Sufficient conduit and panel to handle a 5 kW solar system
- Section R404.3 Electric Vehicle Readiness
  - Minimum AC Level 2 charging capacity
- The F-150 pulls 7.7 kW to 19.2 kW of power in a range of 32-80 Amps
- Typical home battery systems start at around 5 kW per unit
- Typical electrical panel capacities will need to expand significantly to a minimum of 200A to accommodate our clean energy future
- Electricity usage and desired PV plus Battery system sizes will increase with greater adoption of EVs
- Designing homes to optimize and be ready for this future is key

Hawaii Energy

RESIDENTIAL NEW CONSTRUCTION

New construction & major renovation projects can receive rebates for incorporating energy-efficient features into building designs and exceeding building code requirements.

Single Family Homes

Multifamily Projects

PRESCRIPTIVE APPROACH (Single Family (Detached))

Minimum Requirements

85% LED Lighting
50% ENERGY STAR® Appliances Installed
ENERGY STAR® certified (refrigerator, dishwasher, clothes washer, and clothes dryer)

Optional Incentives

High SEER A/C
Smart Thermostats
Ventilation Fans (whole house fan)

Multifamily New Construction Projects

We've increased involvement in the multifamily sector by offering PERFORMANCE APPROACH Incentives for both In-Unit and Common Areas

Custom incentives for Energy-Efficiency measures exceeding current multifamily building requirements (e.g. Solar & Heat Pump Water Heating)

WATER HEATING REBATES

Solar Water Heating $750 INSTANT REBATE

A solar water heater in your home is the best way to save money on your electric bill. With Hawaii Energy's rebate combined with state and federal tax credits, you can save an incredible amount on the system purchase price in the first year.

Heat Pump Water Heater Limited time increase: $500 INSTANT REBATE

Another option for reducing your water heating cost is to install an ENERGY STAR® heat pump water heater for your home. Heat pump water heaters are 2x as efficient as a conventional water heater, cutting your water heating costs in half. Hawaii Energy rebates and federal tax credits make this water heater a very cost-effective upgrade.

https://hawaiienergy.com/for-homes/rebates/water-heating

WATER HEATING RESOURCES

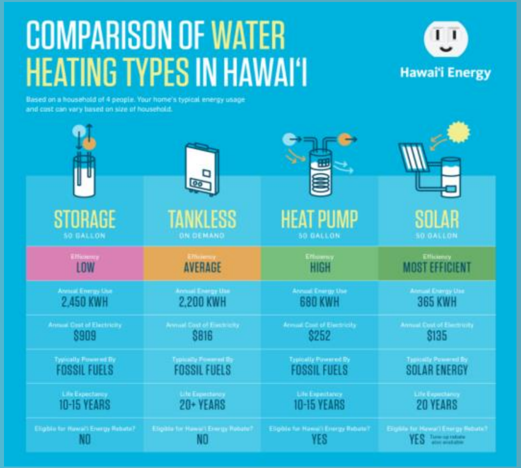
https://hawaiienergy.com/for-homes/water-heating/water-heating-types

https://www.energystar.gov/products/hot-water-heater-replacement-guide

https://www.energy.gov/energysaver/heat-pump-water-heaters

Justin Bizer

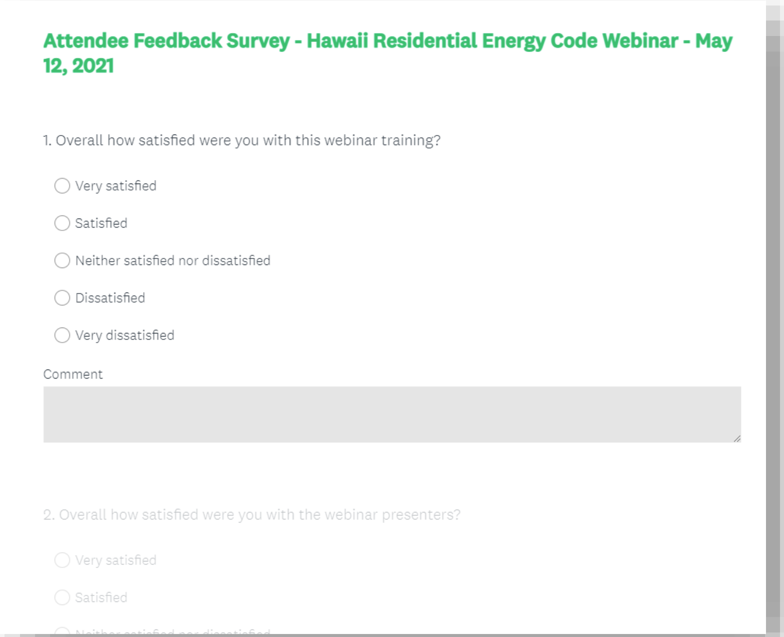
Affordability & Accessibility Programs
Residential New Construction Programs
Justin.V.Bizer@Leidos.com
Office: 808.848.8534



Wrap Up

Evaluation Survey

https://www.surveymonkey.com/r/V6LRM6F



Attendee Feedback Survey - Hawaii Residential Energy Code Webinar - May 12, 2021

1. Overall how satisfied were you with this webinar training?

- Very satisfied
- Satisfied
- Neither satisfied nor dissatisfied
- Dissatisfied
- Very dissatisfied

Comment

2. Overall how satisfied were you with the webinar presenters?

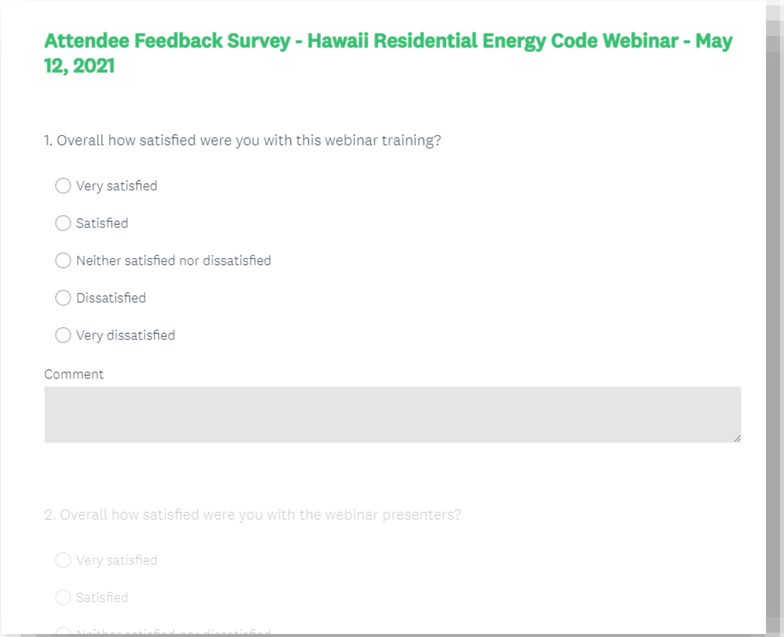
- Very satisfied
- Satisfied

Q&A

Wendy Meguro, meguro@hawaii.edu
Eileen Peppard, epeppard@hawaii.edu
Rocky Mould, rmould@hsea.org
Erik Kolderup, erik@kolderupconsulting.com

Evaluation Survey

https://www.surveymonkey.com/r/V6LRM6F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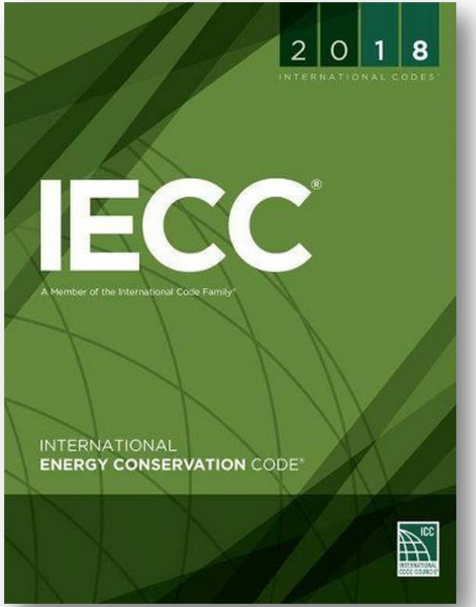
Webinar next week



Complying With the Energy Code – 2018 IECC with Hawai'i Amendments

A new energy code takes effect for Hawai'i State building projects on December 14

Thursday, December 9
Noon – 1:30pm

1.5 AIA HSW learning units

Registration
https://energy.hawaii.gov/hawaii-energy-building-code

Thank you

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HAWAII STATE
Energy Office