MEMORANDUM

Pacific Northwest NATIONAL LABORATORY

Date:	**12/6/2022**		
To:	**Howard Wiig and Gail Suzuki, Hawaii State Energy Office**	Information Release #	**PNNL-179680**
From:	**Vrushali Mendon, Rob Salcido, and YuLong Xie**		
Subject:	**Cost-Effectiveness Analysis of the 2021 IECC for Hawaii**		

The State of Hawaii is in the process of updating their current state residential energy code which is an amended version of the 2015 International Energy Conservation Code (IECC) to the 2021 IECC. The State Energy Office of Hawaii requested an analysis of the energy and economic impacts of the 2021 IECC compared to their current baseline code. Additionally, they also requested an energy analysis of the code provisions pertaining to tropical semi-conditioned single-family buildings compared to a naturally ventilated scenario with ceiling fans. To assess these impacts, PNNL analyzed the energy and cost-effectiveness of adopting the 2021 IECC compared to the amended 2015 IECC adopted by Hawaii using the DOE Residential Building Prototype models and DOE's Residential Cost-Effectiveness Methodology.

Moving to the 2021 IECC is cost-effective for both single-family and low-rise multifamily residential buildings in Hawaii when compared to the amended 2015 IECC currently adopted by the State. The 2021 IECC will provide statewide energy cost savings of 8.6%. This equates to $384 of annual utility bill savings for the average Hawaii household as detailed in Table 1. Further, adopting the 2021 IECC in Hawaii is expected to result in homes that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort, and resilience.

Table 1. Individual Consumer Impact[1]

Metric	Compared to the 2015 IECC with Hawaii Amendments
Life-cycle cost savings of the 2021 IECC	$6,642
Net annual consumer cash flow in year 1 of the 2021 IECC[2]	$325
Annual (year 0) energy cost savings of the 2021 IECC ($)[3]	$384
Annual energy cost savings of the 2021 IECC (%)[4]	8.6%

Methodology

DOE's cost-effectiveness methodology evaluates 32 residential prototypes comprising a single-family detached and a low-rise multifamily building each configured with four foundation types and four HVAC types. The State Energy Office of Hawaii requested elimination of the two basement prototypes to better represent construction trends in the Hawaii. Additionally, single-family buildings in Hawaii have the option of complying with the requirements for tropical semi-conditioned buildings in the IECC. The semi-conditioned tropical building prototype is modeled using the same dimensions as the two-story single-family prototype building, except for only the top story being conditioned. The bottom story is un-conditioned but is assumed to be occupied, thus resulting in similar lighting, appliances and plug loads as the fully conditioned single-family prototype. The semi-conditioned tropical prototypes are included in the overall set of prototypes for this analysis. All prototypes are simulated with TMY3 weather data for Honolulu in Hawaii.

The energy savings from the simulation analysis are converted to energy cost savings using the most recent state-specific residential fuel prices from DOE's Energy Information Administration (EIA).[5,6,7] For electricity, a price of $0.30/kWh provided by the State Energy Office of Hawaii is used instead of EIA data. Fuel prices used in this analysis can be found in Table 2. Fuel prices are escalated over the analysis period based on EIA's year-by-year projections in the 2021 Annual Energy Outlook,[8] Reference Case.[9]

[1] A weighted average is calculated across building configurations and climate zones.
[2] The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc.). First-year net cash flow is reported; subsequent years' cash flow will differ because of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.
[3] Annual energy savings is reported at time zero, before any inflation or price escalations are considered.
[4] Annual energy savings is reported as a percentage of whole building site energy use.
[5] https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3
[6] https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm
[7] https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm
[8] https://www.eia.gov/outlooks/aeo/
[9] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&sourcekey=0

Table 2. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
0.30	4.45	2.52

Construction cost differences between the 2021 IECC and the 2015 IECC with Hawaii amendments were estimated based on DOE/PNNL reports on the cost-effectiveness of new code editions and market research. National cost estimates were adjusted by a Hawaii-specific construction cost multiplier[10] and appropriate Consumer Price Index (CPI) multipliers[11] to yield costs in 2022 dollars.

Life Cycle Cost (LCC) savings is the primary measure DOE uses to assess the economic impact of building energy codes. LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. When the LCC of the updated code (e.g., the 2021 IECC) is lower than that of the previous code (2015 IECC with Hawaii amendments), the updated code is considered cost-effective.

The financial and economic parameters used in calculating the LCC and annual consumer cash flow are based on the latest DOE cost-effectiveness methodology to represent the current economic scenario.[12] The parameters are summarized in Table 3 for reference.

Table 3. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	5%
Loan fees	0.6% of mortgage amount
Loan term	30 years
Down payment	10% of home value
Nominal discount rate (equal to mortgage rate)	5%
Inflation rate	1.6%
Marginal federal income tax	15%
Marginal state income tax	7.6%
Property tax	1.1%

[10] https://www.energycodes.gov/sites/default/files/2021-11/Location_Factors_Report.pdf
[11] https://www.usinflationcalculator.com/inflation/consumer-price-index-and-annual-percent-changes-from-1913-to-2008/
[12] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Consumer Impacts

Moving to the 2021 IECC is cost-effective for households living in single-family and low-rise multifamily units in Hawaii. Based on a 30-year life-cycle cost analysis, the average consumer can expect to save nearly $6,642 and see a positive cashflow in 1 year.

Tables 4 through 6 display typical cost-effectiveness metrics analyzed in US DOE national and state energy code analyses. These metrics include life-cycle cost savings, consumer cash flow timeframe[13], and annual energy cost savings. Tables 7 and 8 show the incremental construction costs when updating to the 2021 IECC based on the single-family fully conditioned, single-family semi-conditioned tropical, and multifamily prototypes used in this analysis.

[13] Consumer Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)

Table 4. Life-Cycle Cost Savings of the 2021 IECC compared to the 2015 IECC with Hawaii Amendments

Climate Zone	Life-Cycle Cost Savings ($)
1AWH	9,023
1AWH (Tropical Semi-Conditioned)	652
State Average	**6,642**

Table 5. Consumer Cash Flow from Compliance with the 2021 IECC compared to the 2015 IECC with Hawaii Amendments

	Cost/Benefit	State Average
A	Incremental down payment and other first costs	$116
B	Annual energy savings (year one)	$397
C	Annual mortgage increase	$64
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$7
E = [B-(C+D)]	Net annual cash flow savings (year one)	$325
F = [A/E]	Years to positive savings, including up-front cost impacts	1

Table 6. Simple Payback Period for the 2021 IECC compared to the 2015 IECC with Hawaii Amendments

Climate Zone	Payback Period (Years)
1AWH	2.3
1AWH (Tropical Semi-Conditioned)	NA
State Average	**2.3**

Table 7. Total Single-Family Construction Cost Increase for the 2021 IECC compared to the 2015 IECC with Hawaii Amendments ($)

Climate Zone	Ceiling Insulation ($/home)	High-Efficiency Water Heater ($/home)	Total ($/home)
1AWH	$0	$1,130	$1,130
1AWH (Tropical Semi-Conditioned)	-$99[14]	$0	-$99

Table 8. Total Multifamily Construction Cost Increase for the 2021 IECC compared to the 2015 IECC with Hawaii Amendments ($)[15]

Climate Zone	High-Efficiency Water Heater ($/dwelling unit)	Total ($/dwelling unit)
1A	$1,130	$1,130

For a more detailed description of the approach PNNL uses to evaluate residential energy code cost-effectiveness, including building prototypes, energy and economic assumptions, and other considerations, please review the latest DOE Residential Cost-Effectiveness Methodology.[16]

Additional Analysis of the Tropical Semi-Conditioned Prototype

The State Energy Office of Hawaii additionally requested an energy analysis comparing the annual energy use of cooling a 900 sq.ft. space using a split air-conditioning system, compared to one that uses four ENERGY STAR ceiling fans. In lieu of building a new single-family prototype building with 900 sq.ft. of conditioned space, the State Energy Office experts agreed to using the tropical semi-conditioned prototype with 1188 sq.ft. of conditioned floor area as a reasonably comparable case.

For the ceiling fans scenario, the 1188 sq.ft. area is assumed to be served by four ceiling fans. Thus, each ceiling fan serves an area of 297 sq.ft. ENERGY STAR guidance[17] suggests a fan size of 50-54” for an area of 225-400 sq.ft. This analysis assumes four fans of 52” for the energy calculation. ENERGY STAR requires a minimum efficiency of 110 cfm/W for ceiling fans between 36” and 72” in diameter.[18] Most fans in the ENERGY STAR database have an efficiency rating of 110-340 cfm/W. These fans consume between 14-27 W at high speeds, depending on the model. Assuming a conservative high-speed fan energy consumption of 27 W

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[14] The 2015 IECC with Hawaii amendments requires R-19 ceiling insulation for the tropical semi-conditioned building types while the 2021 IECC requires R-15. Thus, there is a cost saving associated with this measure.
[15] In the multifamily prototype model, the heated basement is added to the building, and not to the individual apartments. The incremental cost associated with heated basements is divided among all apartments equally.
[16] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf
[17] https://www.energystar.gov/products/lighting_fans/ceiling_fans/ceiling_fan_basics#3
[18] https://www.energystar.gov/products/lighting_fans/ceiling_fans/ceiling_fans_key_product_criteria

and that the fans run at high-speed for 3,000 hours annually, the energy consumed by the fans is estimated to be 80.4 kWh per fan. This works out to $97 for the four fans at $0.30/kWh.

Table 9 summarizes the annual energy costs of cooling the tropical semi-conditioned prototype built to the requirements of the 2021 IECC with an air-conditioning system with SEER 14, compared to the energy consumed by four ENERGY STAR fans as calculated above. If a higher efficiency air-conditioning system such as a SEER 18 system were utilized instead, the costs of air-conditioning would reduce to approximately $1,092 annually.

Table 9. Energy Consumption for the Tropical Semi-Conditioned Prototype with an Air-Conditioning System Compared to ENERGY STAR Ceiling Fans

Tropical Semi-Conditioned Prototype House Energy Costs ($/year)	
Split Air-Conditioner (SEER 14)	**ENERGY STAR Ceiling Fans**
$1,404	$97