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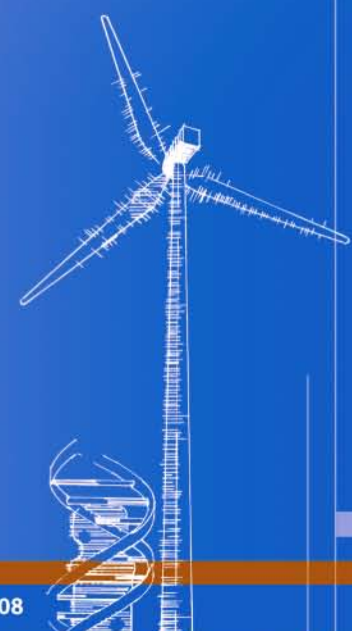
# Hawaii Clean Energy Initiative Existing Building Energy Efficiency Analysis

## November 17, 2009 – June 30, 2010

P. Finch and A. Potes
*Booz Allen Hamilton*
*Honolulu, Hawaii*

***Subcontract Report***
**NREL/SR-7A2-48318**
**June 2010**



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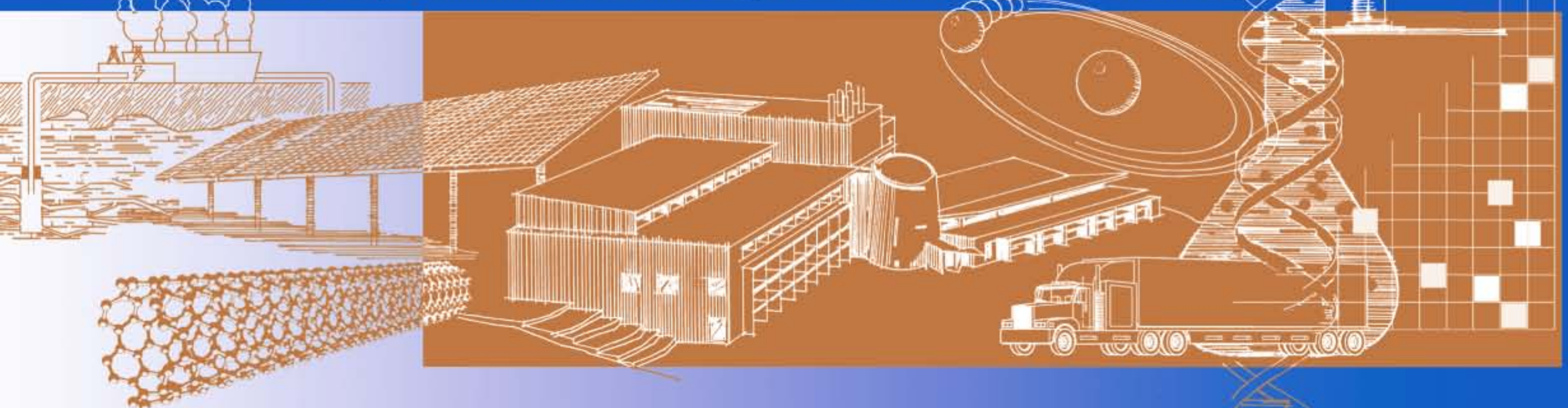

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NREL Technical Monitor: S. Busche



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## List of Acronyms

| | |
|---|---|
| AC | air-conditioning |
| ACEEE | American Council for an Energy Efficient Economy |
| BAH | Booz Allen Hamilton |
| CFL | compact fluorescent lighting |
| DBEDT | Hawaiian Department of Business, Economic Development and Tourism |
| DOE | Department of Energy |
| DSM | demand side management |
| EB | existing buildings |
| EEPS | Energy Efficiency Portfolio Standard |
| EER | energy efficiency ratio |
| EMS | energy management system |
| EPA | Environmental Protection Agency |
| FEMP | Federal Energy Management Program |
| GWh | gigawatt-hour |
| HCEI | Hawaii Clean Energy Initiative |
| HECO | Hawaiian Electric Company |
| HELCO | Hawaiian Electric Light Company |
| IRP | Integrated Resource Plan |
| KIUC | Kauai Island Utility Cooperative |
| kWh | kilowatt-hour |
| LED | light emitting diode |
| MECO | Maui Electric Company |
| MWh | megawatt-hour |
| NAECA | National Appliance Energy Conservation Act |
| NC | new construction |
| NREL | National Renewable Energy Laboratory |
| O&M | operations and maintenance |
| PBF | Public Benefits Fund |
| SEER | Seasonal Energy Efficiency Rating |
| SF | square feet |
| SWAC | seawater air-conditioning |
| WH | water heating |

# Executive Summary

In June 2009, the State of Hawaii enacted an Energy Efficiency Portfolio Standard (EEPS) with a target of 4,300 gigawatt-hours (GWh) by 2030 (Hawaii 2009). Upon setting this goal, the Hawaii Clean Energy Initiative, Booz Allen Hamilton (BAH), and the National Renewable Energy Laboratory (NREL), working with select local stakeholders, partnered to execute the first key step toward attaining the EEPS goal: the creation of a high-resolution roadmap outlining key areas of potential electricity savings. This roadmap was divided into two core elements: savings from new construction and savings from existing buildings. After attaining feedback from the stakeholders, it was determined that BAH would focus primarily on the existing building analysis, while NREL would focus on new construction forecasting. This report presents the results of the Booz Allen Hamilton study on the existing building stock of Hawaii, along with conclusions on the key drivers of potential energy efficiency savings and on the steps necessary to attain them.

In deconstructing the various types of buildings in the state along with their respective energy footprints, Booz Allen Hamilton relied heavily on contributions from various stakeholders, including the Hawaiian Electric Company, Inc. (HECO), the Kauai Island Utility Cooperative (KIUC), the Department of Business, Economic Development and Tourism (DBEDT), and The Gas Company, among others. Combining the data received from these parties, we determined that the highest areas of energy intensity among all building usage categories were concentrated in six specific sectors: (1) offices, (2) hospitality, (3) retail on the commercial side, (4) single family homes, (5) multifamily homes, and (6) high-rises on the residential side. It was therefore determined that, given resource and time constraints, any analysis of potential existing building efficiency savings must begin with these key sectors, which combine to total 62% of the electricity usage in the state overall (BAH 2009b).

Once the dominant energy users were identified, Booz Allen Hamilton evaluated existing state data to determine where best to supplement it with national building technologies and building operation studies. We identified a need for additional state data and worked with the HECO companies and KIUC to administer a limited appliance saturation survey for the Hawaii commercial sector (BAH 2009a). Aggregating these data by building type, we developed building profiles representing both "average" baseline buildings and "efficient" buildings based off of the most efficient currently available technologies.[1] Electricity savings by building type and end use were calculated as the difference in the electricity use between the building profiles. These savings estimates were then adjusted to include the full building stock for each of the six building types.

[1] The commercial baseline and efficiency building profiles include technologies for the following end uses: cooling, lighting, water heating, fans and motors, building controls, building envelope and computers. For the residential sector, we model cooling, lighting, water heating, building envelope refrigeration and other major appliances. Some combination of these applies to all building types. Full details of calculations and assumptions are available in Appendix I.

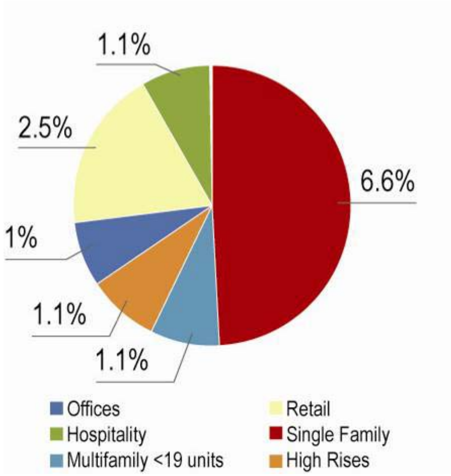


**Figure ES-1. Electricity savings as a percent of 2007 Hawaii electricity usage = 13.5%**

Ultimately, the study determines that the estimated potential savings from the six modeled building types (single family, multifamily below 20 units, high-rises above 20 units, offices, retail, and hospitality) are approximately 1,300 GWh/yr, or 13.5% of 2007 Hawaii electricity use (**Figure ES-1**). HECO projects annual energy use to increase to 14,300 GWh/yr by 2030, and the state energy efficiency target is 30% of this amount, or 4,300 GWh (HECO 2005). Since our model is limited to six building types and based on current energy use, we adjust our results to account for the entire building stock, the growth of existing building loads, and building stock turnover to 2030.

After these adjustments, we estimate that potential electricity savings from existing buildings in 2030 are between 2,100 GWh (15% of 2030 electricity use) and 3,100 GWh (22% of 2030 electricity use). These savings account for approximately half to three-fourths of the 30% state efficiency target.[2] Assuming a levelized cost of $83 per megawatt-hour (MWh) saved[3] (Rogers, Messenger, and Bender 2005), the estimated investment needed to attain required EEPS savings is approximately $4.1 billion by 2030, or $196 million per year. It is anticipated that the private sector will require incentives to make this investment, but the size of the incentives needed is not known at the present time.

[2] The exact value depends on the contribution of additional loads from existing buildings to electricity growth compared to that of new construction.

[3] Due to the extremely high levels of efficiency being targeted by the state, this figure represents a premium over the figure noted in the Rogers, Messenger, and Bender California program study. The first 10% of efficiency attained per building is assumed to cost $50 per MWh, with the per MWh price increasing incrementally as you approach what is technically achievable. This results in an average of $83 per MWh of efficiency for buildings attaining an average electricity use reduction of 25%.

**Table ES-1. Top 5 Individual Efficiency Measure Savings**

| Building Type and End Use | GWh Savings Potential | % of 2007 Electricity Use[4] |
|---|---|---|
| Single Family Water Heating | 250 GWh | 2.5% |
| Single Family Lighting | 194 GWh | 2% |
| Retail Lighting | 85 GWh | 1% |
| Office Cooling | 72 GWh | 1% |
| Single Family Refrigeration | 69 GWh | 1% |

Given the significant projected cost of attaining the EEPS target and constraints on the state efficiency budget, we anticipate that finding additional sources of private investment for efficiency efforts in the state will be critical to successfully meet the efficiency goals. Additionally, attaining the efficiency goals will require building retrofits on the order of magnitude of 80% of the current building stock in the state, as well as building retirements and new construction equal to approximately 20% of the current building stock. Enrollment in existing efficiency programs lags this 80% estimate by a substantial margin, with below 20% of the existing building stock currently engaged in the state efficiency programs. Therefore, outreach and education programs on the benefits of efficiency to building owners should be another key area of focus for the state to move forward.

[4] Due to the uncertain nature of how load growth and efficiency by category type will fluctuate, projections of what each efficiency measure savings will be as a fraction of 2030 energy usage is outlined here.

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# Introduction

The Hawaii Energy Efficiency Portfolio Standard (EEPS) was enacted in bill HB 1464 of the 2009 Hawaii State Legislature (Hawaii 2009). This legislation mandates that by 2030 the state reduce its annual electricity consumption by 4,300 gigawatt-hours (GWh), or 30% of the Hawaiian Electric Company (HECO) forecasted “Business as Usual” 2030 energy consumption of 14,300 GWh/yr (HECO 2008, HELCO 2007, MECO 2007, KIUC 2008). Currently, the state is funding energy efficiency programs through a Public Benefits Fund (PBF) at a rate of approximately $20 million per year to the commercial and residential building sectors, or $21 million total including Kauai Island Utility Cooperative (KIUC) programs, which are administered separately from the PBF’s (HCEI 2009, KIUC 2010). To inform future policy initiatives and funding, the Hawaii Clean Energy Initiative created a roadmap to determine how the state is to meet the 2030 EEPS target. For the purposes of this analysis, all savings achieved are assumed to be maintained until the target date of 2030, so that savings from initial investments do not depreciate over time. However, we fully acknowledge that significant operations and maintenance (O&M) and retro/recommissioning costs may accrue over time, and that efforts in this regard are essential to the success of attaining the EEPS.

The roadmap analysis was divided into two components: efficiency savings from new construction and energy savings from existing buildings. When the EEPS goal was set, the projected contribution in efficiency savings from each of these components was estimated to be 73% (3,150 GWh annually in 2030) from existing buildings and 27% (1,150 GWh annually in 2030) from new construction. The National Renewable Energy Laboratory (NREL) undertook new construction modeling, and this study represents Booz Allen Hamilton’s (BAH’s) analysis (with significant input from local stakeholders) of existing buildings.

Given the limited resources available to the Hawaii PBF and KIUC to devote to efficiency programming to meet the EEPS, a cost-effective distribution of resources that focuses on the building and technology types with the greatest potential electricity savings is essential. The purpose of this study is twofold: to identify the building types and current building technologies with the greatest opportunities for electricity savings, and to estimate potential electricity savings from all existing buildings in 2030. While past estimates of Hawaii efficiency potential exist, they are somewhat dated (HECO 1994, HECO 2004), and they were not conducted in the context of the EEPS. The ultimate goal of this study is to assist program managers in making informed decisions on the optimal building types and end use technologies on which to devote funds to maximize potential electricity savings.[5] See Appendix I for the full list of end use technologies evaluated.

## Methodology

In designing our study, BAH followed a six-step process (**Figure 1**). Using data provided from the state's four electrical utilities, the Hawaii Department of Business, Economic Development and Tourism (DBEDT), and The Gas Company, we began by mapping electricity usage across the entire building stock, by building type (Step1). Next, given time and resource restrictions, we screened for the largest efficiency drivers and built electricity use profiles of "average" and "efficient" versions of these buildings and technology types (Steps 2 and 3). We compared these building models to estimate potential electricity savings (Step 4) and scaled up the savings to reflect the potential efficiency available from the entire building stock (Step 5). The goal of the analysis is to identify building types and efficiency measures that will be the primary drivers of electricity savings across the entire building stock and to compare them to the EEPS goal. Once the largest impact areas of focus were identified, we highlighted secondary areas of focus and any behavioral changes that may be necessary to facilitate energy savings to ensure a holistic approach to forecasting potential savings (Step 6).

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[5] It is essential to note that, unlike previous Hawaii efficiency studies, cost-effectiveness is **not** emphasized as an essential component of this building technology analysis. Instead, the emphasis is on attainment of the EEPS goal and estimating the amount of funding needed to attain the required level of savings. A quantitative cost-effectiveness screen is not applied because the basis of this study is to identify the building and technology types required to reach the 30% target. While we acknowledge that not all measures necessary to attain the target may currently be cost effective and that omitting these measures would leave the state well short of the necessary goal, we also realize that cost-effectiveness for individual measures varies especially widely on a per-building basis for *existing building* retrofits. Therefore, we do not want to rule out technology types that may end up being cost effective in certain situations. Furthermore, given the long duration of the study period, we expect cost-effectiveness to change over time for various measures. Developing long-term technology cost curves was deemed outside of the scope of this study in its original conception.

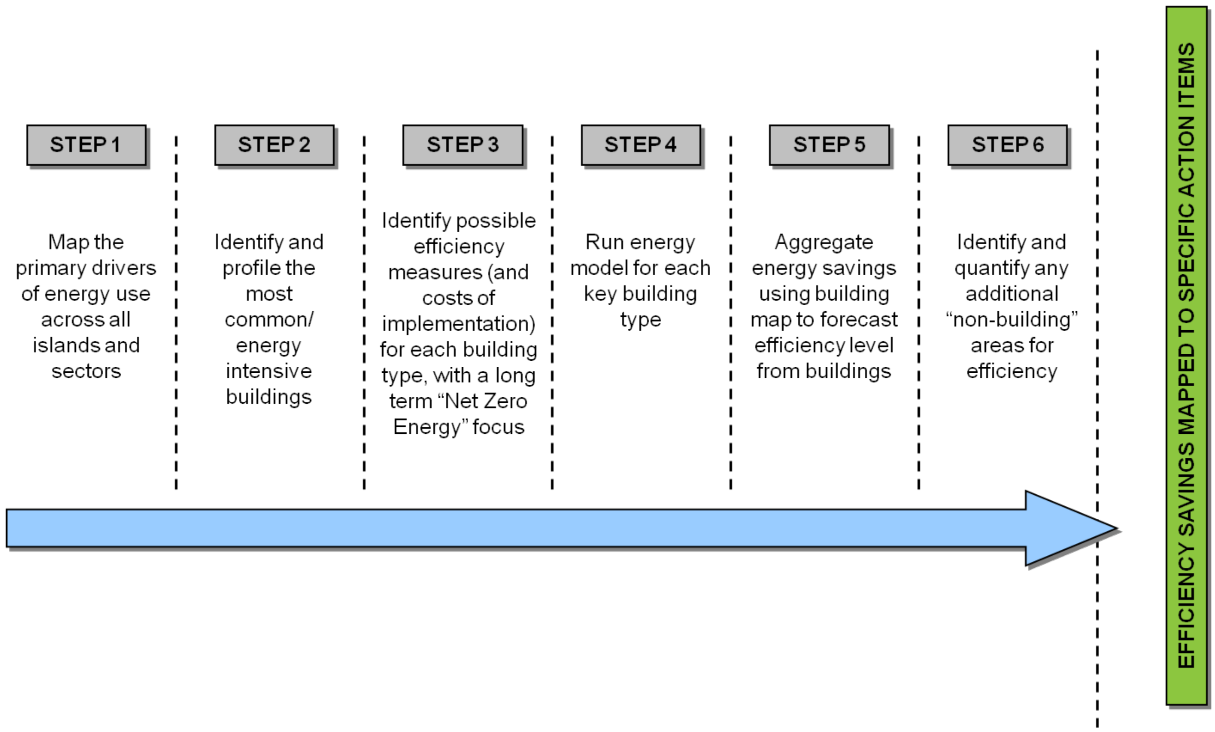


**Figure 1. Analysis methodology**

Steps 2, 3, and 4 require estimating energy savings potential for selected building types, end use technologies, and efficiency measures. We assembled models of individual buildings for two scenarios: a baseline building and an efficient building. For the commercial sector, we overcame limits on the availability of data by aggregating older, Hawaii-specific building efficiency studies with newer Hawaii building survey data and, where necessary, more recent non-Hawaii data. Assuming that equipment efficiencies, sizes, and saturations are normally distributed across the existing building stock, we used older data as representative of the left side of the efficiency curve and more recent data as representative of the right side of the curve. Thus, the average of these data represents our best estimate of the average building in the existing stock (**Figure 2**). For commercial buildings, we assumed that values from the 1994 HECO Commercial Energy-Use Survey (HECO 1994) and the HECO 2004 Integrated Resource Plan-3 Demand-Side Management Report (HECO 2004) represent the least efficient buildings, or the left side of the building stock efficiency curve. To construct an estimate of the most efficient end of the commercial building efficiency curve, Booz Allen teamed with HECO and KIUC to administer a limited appliance saturation survey (BAH 2009a), which supplied the team with data on the high-performing customers currently enrolled in HECO and KIUC's building efficiency programs.

For residential buildings, appliance sizes and unit energy consumptions were derived from the 2008 HECO Residential Appliance Survey (HECO 2009b). These values were not averaged, since the 2008 appliance survey represents a more recent distribution of equipment in the current building stock, but they were compared to the HECO 2004 residential building profiles (HECO 2004) and the 2005 KIUC energy efficiency study (KEMA 2005) for consistency.

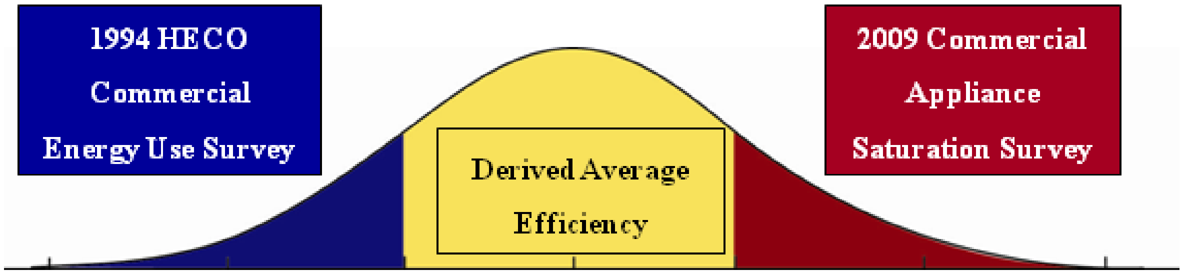


**Figure 2. Hawaii commercial existing building efficiency curve and building profile methodology summary**

- The area under the left side of the curve represents the saturation and energy usage of technologies for the most inefficient buildings in the state.
- The area under the right side of the curve represents the saturation and energy usage of technologies for the most efficient buildings in the state.
- The goal is to capture the most prevalent and efficient of the full range of technologies in the current building stock by averaging the most and least efficient technology saturations and energy usages for each individual technology type within a given building class.

Once baseline models were built for each building type, efficient building profiles were constructed to calculate electricity savings potential by technology and building type. Values for electricity savings by efficiency measure were taken from a combination of Federal Energy Management Program (FEMP) equipment requirements (FEMP 2010), the 2005 KIUC efficiency study (KEMA 2005), the 2008 study on water heater demand-side programs (KEMA 2008), and the 2004 HECO IRP-3 modeling results (HECO 2004). The calculations and values for each individual baseline and efficient building model (including values for end use efficiencies, sizes, saturations, and efficiency measure savings) are detailed in Appendix I.

To avoid overreliance on future technology development in our forecast, we excluded technologies that are not yet commercially viable from the initial building models. However, given that some future technology adoption is likely, we examined potential savings from second-generation technologies, such as seawater air-conditioning (SWAC) and Light-emitting diodes (LEDs), as an addendum to the initial analysis, to project the possible impact of future technologies.

Once the per-building efficiency potential was calculated by building type, we scaled up from individual buildings to the entire existing building stock by multiplying electricity savings by the number of buildings for each building type. The number of buildings for each building type is calculated by dividing the total 2007 electricity use per building type (BAH 2009) by electricity use per baseline building profile developed in this analysis. To correct for building retirement, the model assumes a 1% per year building retirement rate (equivalent to that assumed by the

EEPS[6]). As values for energy use are available by island, we also calculated aggregate savings by island and building type.

Next, as the modeled building sectors represent only 62% of the electricity used by the existing building stock, we scaled up the aggregated results to estimate the potential efficiency savings available from the entire existing building stock. We assumed that the modeled buildings are representative of the entire building stock and that energy savings will be available at the same rate for the entire excluded building stock. The largest portion of the remaining 38% of the building stock electricity use consists of military residential and office buildings (12% of 2007 electricity use), which is largely similar to the sectors included in this analysis. While we realize that there may be some deviation in savings across the remaining 26%, we believe that the six sectors evaluated in this report, plus the military sector, strongly correlate with the end results. While building-specific differences may alter the end numbers slightly, we do not believe the differences are significant to directionally alter the outcomes of this study.

Finally, we adjusted for existing building load growth from 2010 to 2030. As technology saturations change into the future (i.e., more buildings have cooling equipment) and some technologies become more energy intensive (e.g., some television models and added entertainment systems), the efficiency savings potential from existing buildings will increase. Because it is difficult to accurately estimate the increase in existing building load growth from the expected growth in overall energy usage, we estimated a range of potential savings (and potential contribution to the EEPS goal) in 2030 **(Figure 3)**. The lower bound of the range represents zero existing building load growth and the upper bound of the range represents electrical load growth at a ratio of 30% from new construction and 70% from existing buildings.[7]

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[6] Based on 2000 U.S Census building age data, average lifespan of a building in the United States is 70 years; over 20 years approximately two-sevenths of the building stock would turn over, or ~1% per year, [CENSUS 2000a].

[7] Based on historical population growth figures (DBEDT 2008b), utility IRP forecasted energy demand (HECO 2008, KIUC 2008, MECO 2007, HELCO 2007), and BAH-estimated building energy usage (Appendix I)

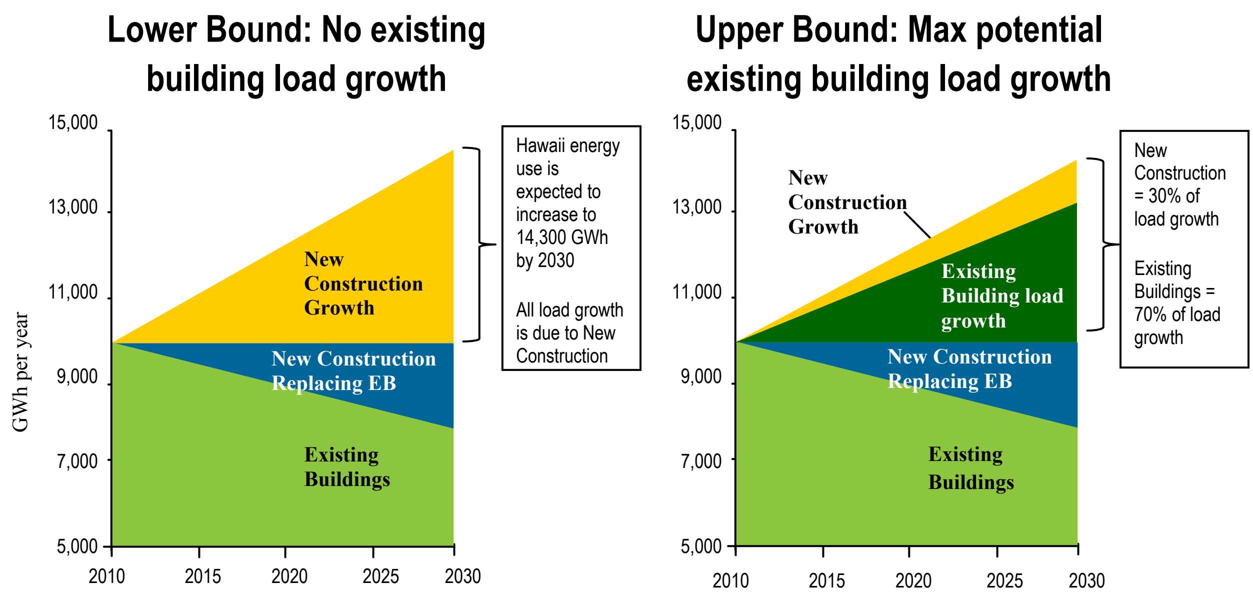


**Figure 3. Hawaii 2030 load growth scenarios**

# Results

## Based on 2007 Electricity Usage Levels

**Figure 4** represents all of the electricity usage drawn from the Hawaii grid in 2007 (post-line loss). The residential sector comprises roughly 32% of this electricity use and includes single family housing, multifamily housing (less than 20 units) and high-rises (20 or more units). The remaining 68% is consumed by twelve commercial sector uses. The aggregate mapping results show that Hawaii electricity use in 2007 was approximately 9,900 GWh/yr and is forecast to grow up to roughly 14,300 GWh/yr by 2030 (BAH 2009b; HECO 2008, MECO 2007, HELCO 2007, KIUC 2008).[8]

[8] This 14,300 GWh figure reflects demand forecasts in the HECO IRP-4 and the HELCO, MECO, and KIUC IRP-3s to set a baseline for the 2010–2030 time frame. It does not make allowances for the potential increasing adoption of plug-in hybrid vehicles moving forward. Increased use of plug-in vehicles may elevate demand for both home and business electricity usage, as the vast majority of vehicle charging will take place at these locations. This did not impact our forecasts in this analysis, as the goal of 4,300 GWh was set independent of forecasts for PHEV demand, and no assumed efficiency gains were forecast to come from electric vehicle efficiency improvements over the 2010–2030 time frame.

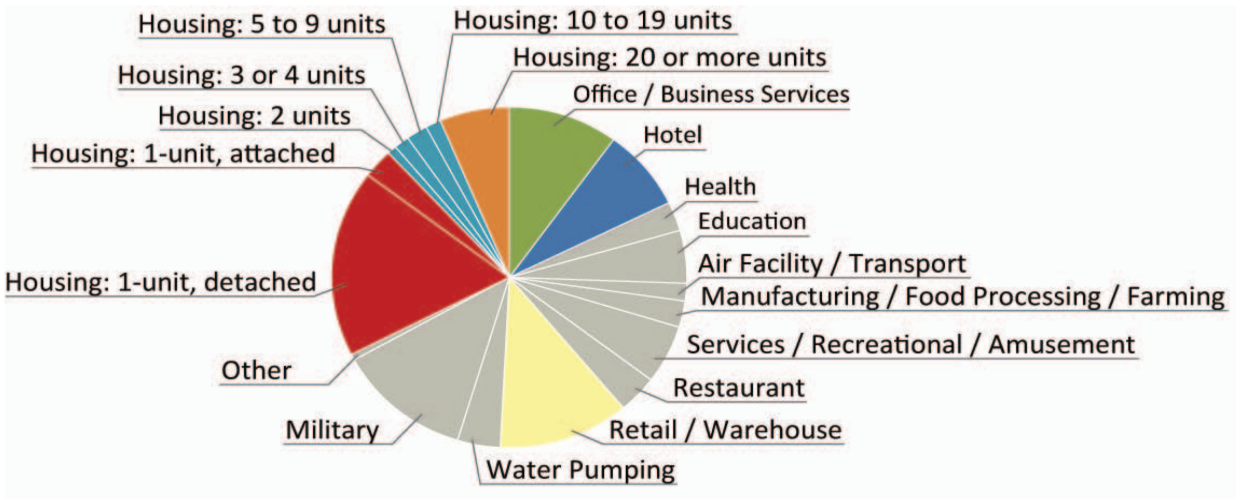


**Figure 4. 2007 Electricity use in the state of Hawaii (MWh)**

Based on the various magnitudes of energy usage indicated by the mapping effort, BAH selected the six highlighted building types that, combined, use 62% of Hawaii's electricity profile (**Figure 4**).[9] For this analysis, the military sector, although large, was excluded from our detailed review, as it is not under state jurisdiction. All sectors were not evaluated due to time and budgetary constraints, but given the significant footprint of the selected sectors in combination with that of the military, Booz Allen, in consultation with the stakeholders, determined that they represented a reasonable proxy for the entire Hawaii building stock and should be considered first.

Similar to screening for large building types, we limited our analysis to large energy usage drivers within each building type. Cooling, lighting, water heating, fans and motors, building controls, building envelope and computers were modeled for commercial buildings. Cooling, lighting, water heating, building envelope, refrigeration and other major appliances were modeled for residential buildings.

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[9] By sector: single family homes (attached + detached): 2.0 million MWh, or 20.5%; multifamily homes (less than 20 units): 5.5 million MWh, or 5.6%; high-rise: 6 million MWh, or 6.1%; retail: 1.2 million MWh, or 12.1%; office: 1 million MWh, or 10.1%; hospitality: 7.6 million, or 7.7%

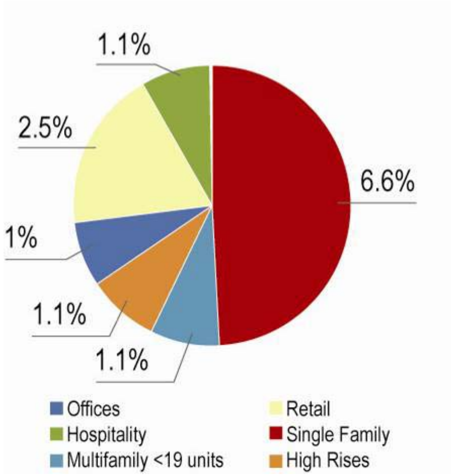


**Figure 5. Electricity savings as a percent of 2007 Hawaii electricity usage = 13.5%**

Should the advised retrofits be adopted across 80% of Hawaii single family, multifamily, office, retail and hospitality existing buildings, the aggregate savings potential is approximately 1,300 GWh, or 13.5% of the total 2007 Hawaii electricity use. By building type (See **Figure 5**), single family homes represent the largest amount of savings potential at 6.6% of 2007 electricity use. The remaining potential savings is represented by retail ( 2.5% of 2007 electricity use), high-rises (1.2%), the hospitality sector (1.1%), multifamily homes (1.1%), and offices (1%).

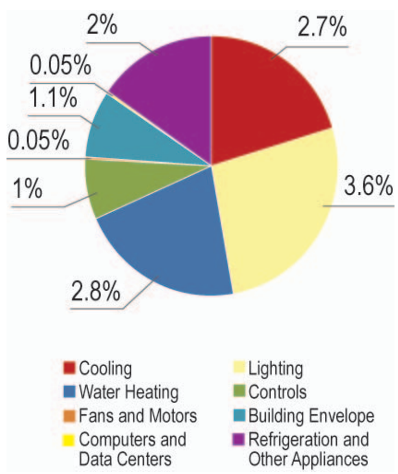


**Figure 6. Electricity savings by end use as a percent of 2007 Hawaii electricity usage**

By end use (**Figure 6**), lighting is the technology with the greatest energy savings potential, at 3.6% of 2007 electricity use. The remaining potential savings is represented by water heating (2.8% of 2007 electricity use); cooling (2.7%); appliances, including refrigeration (2.1%); building envelope improvements (1.1%); lighting and building temperature controls (1%); fans and motors (0.05%); and computers and data centers (0.05%).

By island (**Figure 7**), Oahu has the greatest potential for savings over 2007 electricity use at 9%, followed by Hawaii (1.9%), Maui (1.8%) , and Kauai (0.8%).

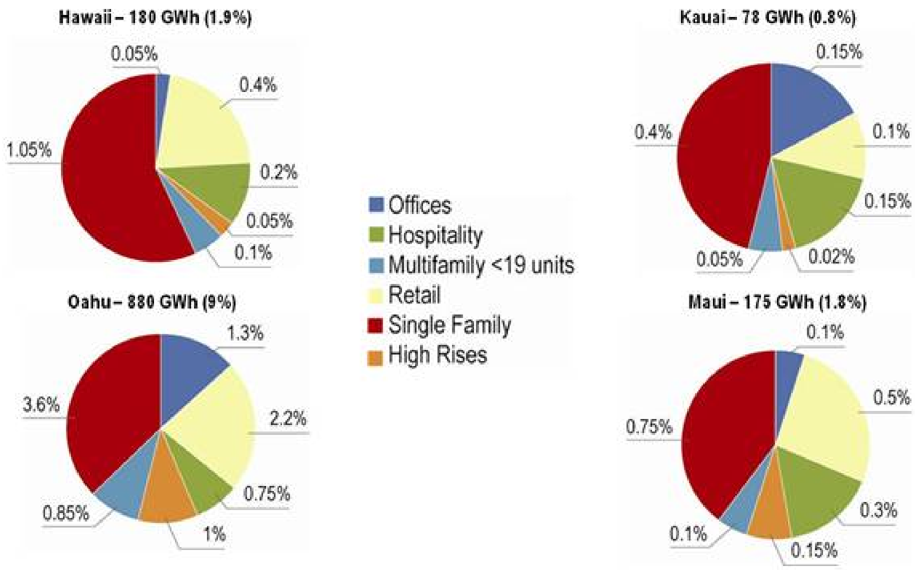


**Figure 7. Electricity savings by island as a percent of 2007 Hawaii electricity use**

Results are also tabulated on a per-building basis for each model building type (Figure 8–Figure 14). For the residential sector, the average high-rise can save 23% of total energy use, the average single family home can save 38%, and the average multifamily home can save 24%. In the commercial sector, large offices can save 12%, small offices can save 20%, retail buildings can save 26%, and hospitality buildings can save 18%.

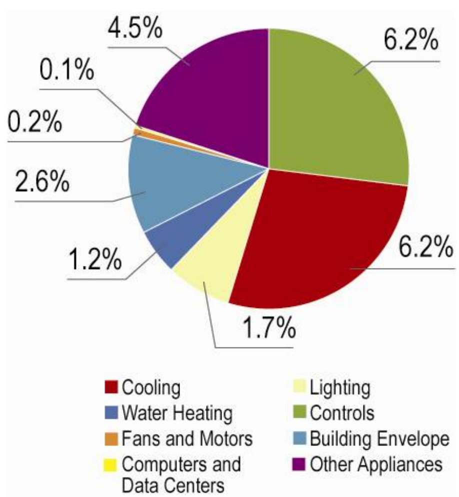


**Figure 8. High-rise profile savings**

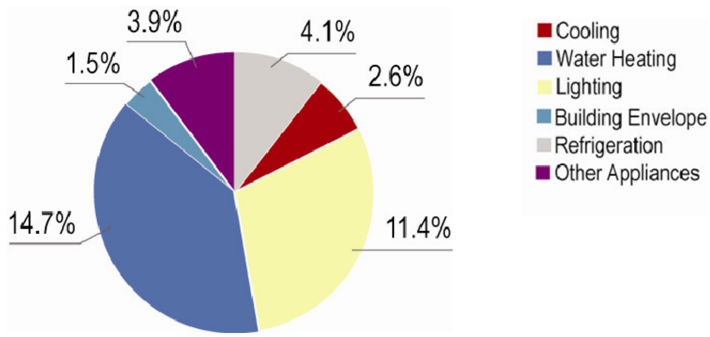


**Figure 9. Single family profile savings**

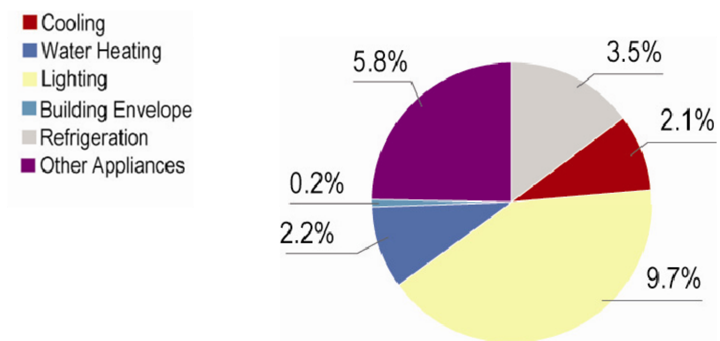


**Figure 10. Multifamily profile savings**

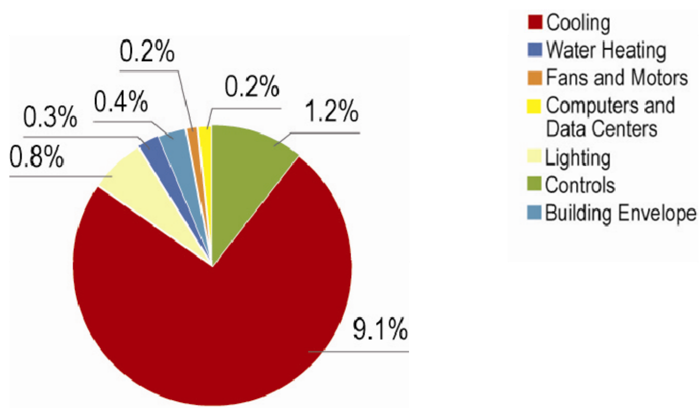


**Figure 11. Large office profile savings**

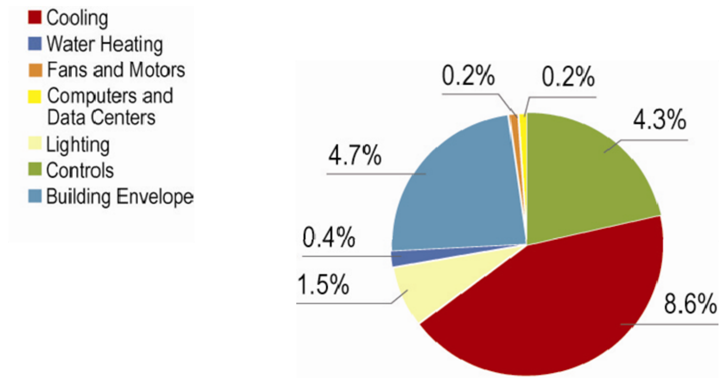


**Figure 12.Small office profile savings**

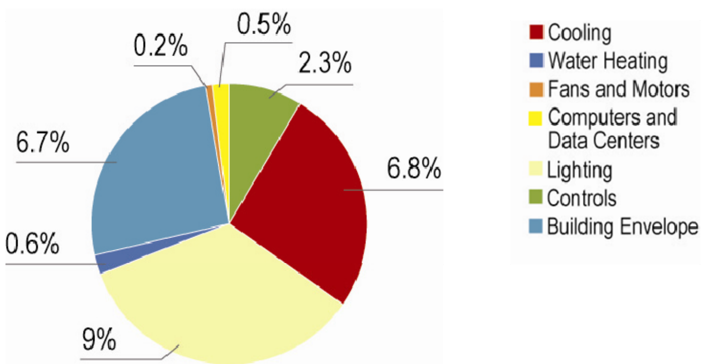


**Figure 13. Retail profile savings**

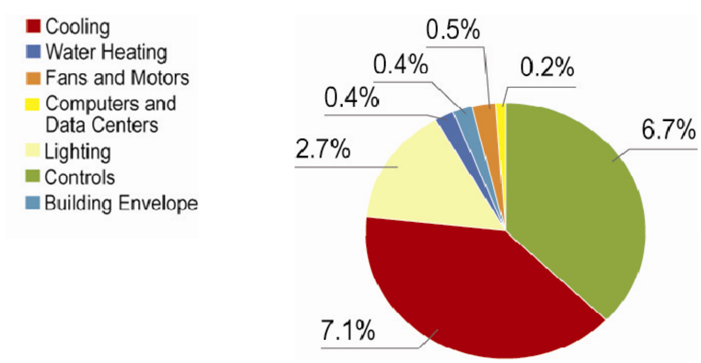


**Figure 14. Hospitality profile savings**

Combining building types and end-use technologies (See **Table 1**), single family water heating presents the greatest opportunity for efficiency improvements, with a potential savings of 250 GWh.

**Table 1. Top 5 Individual Efficiency Measure Savings**

| Building Type and End Use | GWh Savings Potential | % of 2007 Electricity Use[10] |
|---|---|---|
| Single Family Water Heating | 250 GWh | 2.5% |
| Single Family Lighting | 194 GWh | 2% |
| Retail Lighting | 85 GWh | 1% |
| Office Cooling | 72 GWh | 1% |
| Single Family Refrigeration | 69 GWh | 1% |

Other primary electricity efficiency drivers are single family lighting (194 GWh), retail lighting (85 GWh), office cooling (72 GWh), and single family refrigeration (69 GWh). A full list of aggregate efficiency savings by building type and end use is available in Appendix I.

Finally, once the potential electricity savings from these six building type is calculated, we adjusted to incorporate those buildings in the additional 38% of the building stock not accounted for in these six categories. Taking the average savings across all six building types (22% electricity savings per building) and applying it to the energy usage for the remaining building types results in an additional potential savings of 800 GWh, bringing the potential savings for the entire existing building stock up to 2,100 GWh overall, or roughly 22% of Hawaii 2007 electricity use.

### Results Adjusted for Load Growth (2008–2030)

It is important to note that the EEPS is 30% of Hawaii electricity use in 2030, so to make a true longer-term projection, we must compare potential savings to the projected energy use in our end scenario, the year 2030, as opposed to the static 2007 electricity use context provided in the preceding section. The projected *annual* increase in electricity usage above 2007 levels in the year 2030 is 4,500 GWh,[11] including increased usage from both new construction and existing buildings (the energy intensity of an average building is forecast to increase over time with the adoption of more extensive air-conditioning units and more energy-intensive appliances).

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[10] Due to the uncertain nature of how load growth and efficiency by category type will fluctuate, projections of what each efficiency measure savings will be as a fraction of 2030 energy usage is outlined here.

[11] Projected growth is calculated by subtracting 14,333 GWh (HECO 2005) minus 9,859 GWh (BAH 2009b; HECO 2005).

Since a detailed breakdown of these components of expected growth is not available, we have determined instead a likely range for potential electricity savings relative to projected 2030 electricity use, based on "minimum growth in existing buildings electricity demand" (Lower Bound) and "maximum potential growth in existing buildings electricity demand" (Upper Bound) scenarios (Also illustrated in **Figure 3**):

- Lower Bound: If there is no growth in existing building load, potential savings will not grow over time, capping the existing buildings portion of the final savings figure at 2,100 GWh (15% of 2030 electricity use), or approximately 50% of the 4,300 GWh EEPS goal.
- Upper Bound: If new construction grows to match historical population growth fully (0.7% per year [DBEDT 2008b]), equivalent to 30% of all new energy usage coming from new construction (based on utility 2007–2008 IRPs and BAH-estimated per-building energy usage [Appendix I]), but the entire remaining electricity growth forecast comes from existing buildings, potential existing building savings will equal 3,100 GWh, or 22% of 2030 Hawaii electricity use, maintaining existing buildings' approximate 70% share of the state EEPS goal.

This 50%–70% range for the existing buildings' contribution to the efficiency goal indicates that the targeted 70% contribution, estimated when the EEPS was enacted (Hawaii 2009), is a possibility (albeit a lower probability contingent on the balance of load growth between new construction and existing buildings moving forward).

Despite the variability in expected savings from existing building load growth, these added savings are not expected to change the modeling results of the primary building types on which policy should be focused. Cooling savings will likely increase with increased cooling equipment saturation, but cooling is already at the top of the list for efficiency savings potential. Any assumption about appliance growth, particularly the increase in home entertainment equipment saturation, is difficult to accurately include in the model. This added growth is not likely to be significant enough to become a primary efficiency driver, as the average entertainment equipment electricity consumption reflects a small percentage of Hawaii electricity use. For example, a plasma television is the most energy-intensive home entertainment appliance, using 441 kilowatt-hours (kWh) per year on average. This end use is only roughly 5% of the electricity use of an average single family building.

# Conclusions

Once we established the level of savings needed, a general cost analysis was conducted, and conclusions were drawn on a number of key points essential to the attainment of the state goals. To be implemented effectively, the following recommendations rely heavily on collaboration between the public sector (state agencies, the PBF administrator) and the private sector (utility companies, private businesses, building owners) across a wide range of issues, including the identification and testing of technologies, the raising and investment of capital, the education of the public, and the refinement of existing programs.

- *Additional investment, on the order of $50 million to $100 million per year, is necessary to meet the Hawaii EEPS targets.*

  Private investment in energy efficiency is critical to Hawaii's meeting its efficiency target, and it is apparent that much will be necessary above and beyond what is already provided by the public sector via utility programs and contributions to the state's PBF. Based on a levelized cost of energy efficiency of $83 per megawatt-hour (MWh) (Rogers, Messenger, and Bender 2005) and linear projections from 2010 to 2030, the total cost to meet the EEPS target (regardless of source) would be $4.1 billion, or $196 million per year. Assuming existing building efficiency savings will contribute 50-70% to the EEPS target (See "Results Adjusted for Load Growth" section for the calculation of this range), then the funding needed for existing buildings would be $98 million to $137million per year ($196 × 50%70%). Currently, KIUC annual program funding is $1 million (KIUC 2010), and the Hawaii PBF funding for efficiency savings is roughly $20 million per year (HCEI 2009).[12] Additionally, according to our analysis, the military accounts for 12% of Hawaii electricity use. Assuming the military matches the 30% efficiency goal with its own pool of funding separate from that of the state as a whole, we assume that the costs for those improvements can be subtracted from the total costs to achieve the EEPS (12% × $196 million = $24 million). Thus, total additional investment (either private or public) needed to meet the existing building portion of the state's efficiency goal would be in the $53 million to $92 million range per year ($98 million to $137 million minus $45 million.) Given the ratio of existing building energy use between the residential and commercial sectors,[13] the residential sector will need an additional $24 million to $41 million per year ($53 million to $92 million × 45%), and the commercial sector will need an additional $29 million to $51 million per year ($53 million to $92 million × 55%), with much of this being contributed by the private sector. Thus, finding ways for public money to leverage high levels of private capital becomes essential to the attainment of the EEPS goal.

[12] $19.6 million per year is equivalent to roughly 0.6% of the total expected revenues for HECO, HELCO, and MECO. As revenue is expected to increase over time, PBF funds generated will increase to a predicted $60 million per year by 2014 (HCEI 2009).

[13] As the cost for energy efficiency retrofits is estimated based on "percentage improvement reached" (see footnote 2 in Executive Summary for overview), the $83/MWh cost assumed in this study reflects an average of commercial and residential retrofit projects. Therefore, we do not make a differentiation in cost between the two sectors here.

- *Given our assumption of cumulative 20% building turnover from 2010 to 2030, successfully identifying and retiring these buildings to maximize cost effectiveness would allow Hawaii to optimize efficiency gains.*

  The model assumes a 1% rate of building turnover per year and a total building turnover rate of 20% of the existing building stock by 2030. To maximize the amount of electricity savings from retrofits, the least viable candidates for retrofit must be identified and targeted for replacement with more efficient new buildings, while retrofit efforts are targeted at the buildings that are capable of being cost-effectively retrofitted. This is due to the fact that most buildings in the lower 20% of the energy efficiency curve are too costly to retrofit, so if they are not replaced, they will continue to act as a drag on the state's energy reduction efforts. Therefore, those buildings that can be retrofitted cost effectively should be upgraded, while those that will never be cost effective to retrofit should be replaced entirely. This will generate the maximum efficiency savings from both existing buildings (more retrofits will happen), as well as from new construction (highly efficient new construction replaces the worst of the energy users).

- *Full participation in retrofit and efficiency programs is essential to meeting the EEPS target.*

  Given the 20% overall building retirement assumption, an estimated 80% of Hawaii's buildings must participate in efficiency efforts for the state to meet the EEPS target. It was assumed that 20% of building owners enroll voluntarily in retrofit programs, which is a large portion of the overall population to enroll in any single public program. This leaves 60% of the building stock currently unaccounted for. Given policy initiatives that correctly target building and technology areas, additional outreach and education must be designed to achieve the retrofitting of as much of this 60% of the building stock as possible. It is also quite likely that our hypothetical 20% assumption is too optimistic, which would make the importance of outreach and education programming even greater.

- *Advanced technologies, not yet deployable, must play a role in creating efficiency savings to offset shortfalls in savings from non-cost-effective current technology.*

  An important caveat to our calculation of available savings is that some of the energy efficiency measures that are considered will not prove cost effective for all buildings types.[14] For example, building envelope retrofits to insulation are an expensive energy efficiency measure, and unlikely to be adopted in many cases, even when applicable. Where possible, Hawaii should seek to increase per building efficiency savings through the use of next-generation technologies. One possibility is LED lighting. If all

[14] The purpose of this study is to identify technologies that will be required to meet the 30% EEPS goal. To chart these technologies, we make the initial assumption that not all of them will be cost effective. Deployment of technologies that are not yet commercially viable can help offset these costs.

incandescent and CFL lighting is replaced with LED lighting, the modeled existing buildings could obtain an additional 134 GWh of savings (DOE 2010), or about 1.4% of 2007 state electricity use. SWAC is another example of a technology option under development. HECO estimates that a proposed Waikiki SWAC site could offset 140,000 MWh of cooling energy, equal to another 1.4% of 2007 electricity use (HECO 2010). As such, the development of pilot programs for new technologies to identify promising ones and to verify their performance becomes of key importance to the long-term attainment of any lofty efficiency goal such as the one in the EEPS.

- *In order to increase the effectiveness of efficiency policy, retro/recommissioning and O&M training should be incorporated into technology policy.*

  Efficiency savings estimates are based on manufacturer data and may not represent real-time results because of improper installation, calibration, and maintenance. Proper building commissioning and O&M are essential to achieving the full savings potential of retrofits, as building operators may be unfamiliar with new technologies. The proper operation of building controls, particularly, should be a focus of this type of policy because this equipment can have a large impact on building energy use for minimal cost as long as it is installed and operated correctly. A recent Lawrence Berkeley National Laboratory metadata study estimates average electricity savings of approximately 9% from the commissioning/retrocommissioning of a wide range of building types (Mills and Mathew 2009). Thus, the building commissioning will be a significant source of ongoing savings that is essential to the real-time reduction of electricity usage statewide.

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## Appendix I: Study Assumptions and Calculations

The full list of aggregated potential energy savings by sector and end use is included in **Table 2** (below).

**Table 2. Total Aggregate Savings by Building Type and Technology (State-wide)**

| | Potential Electricity Savings (GWh/year) |
|---|---|
| **Offices** | |
| Refrigeration | Did Not Estimate |
| Cooling | 72 |
| Lighting | 6 |
| Water Heating | 3 |
| Controls | 10 |
| Fans and Motors | 1 |
| Building Envelope | 4 |
| Appliances | Did Not Estimate |
| Computers and Data Centers | 1 |
| **Retail** | |
| Refrigeration | Did Not Estimate |
| Cooling | 64 |
| Lighting | 85 |
| Water Heating | 5 |
| Controls | 22 |
| Fans and Motors | 2 |
| Building Envelope | 63 |
| Appliances | Did Not Estimate |
| Computers and Data Centers | 4 |
| **Hospitality** | |
| Refrigeration | Did Not Estimate |
| Cooling | 43 |
| Lighting | 17 |
| Water Heating | 3 |
| Controls | 41 |
| Fans and Motors | 3 |
| Building Envelope | 3 |
| Appliances | Did Not Estimate |
| Computers and Data Centers | 1 |
| **High-Rises** | |
| Refrigeration | 22 |
| Cooling | 31 |
| Lighting | 8 |
| Water Heating | 6 |
| Controls | 31 |
| Fans and Motors | 1 |
| Building Envelope | 13 |

| | |
|---|---|
| Appliances | 33 |
| Computers and Data Centers | 1 |
| **Single Family** | |
| Refrigeration | 70 |
| Cooling | 46 |
| Lighting | 194 |
| Water Heating | 250 |
| Controls | Did Not Estimate |
| Fans and Motors | Did Not Estimate |
| Building Envelope | 18 |
| Appliances | 66 |
| Computers and Data Centers | Did Not Estimate |
| **Multifamily** | |
| Refrigeration | 15 |
| Cooling | 9 |
| Lighting | 43 |
| Water Heating | 10 |
| Controls | Did Not Estimate |
| Fans and Motors | Did Not Estimate |
| Building Envelope | 0 |
| Appliances | 25 |
| Computers and Data Centers | Did not estimate |

These figures represent the difference in energy usage from the efficient case to the baseline case for each building type, aggregated across the full number of buildings in each category for the state.

While the total number of housing units in the state is known, due to a lack of detailed information on the number of commercial buildings, the total number of commercial buildings assumed for each category is back-calculated from their total electricity usage. Thus, our model profiles may represent in certain commercial building cases an average building that is the equivalent of multiple smaller buildings, all with the same baseline characteristics and efficiency options. While this represents an accurate picture of statewide potential savings, as we account for the full electricity usage in each sector, it may mean that for certain building types we are assuming a smaller number of buildings than exist in the current building stock. This correspondingly reduces the number of retrofits needed but is compensated for by an increase in the size of each individual retrofit in absolute terms (although not in percentages). An example: three small buildings retrofitted at a 20% savings level, if added together, form the equivalent one larger building retrofitted at a 20% savings level, provided the same combination of energy conservation measures is applied to each. Therefore, the accuracy of the total energy savings is not compromised, but it would not be correct to assume energy savings per building applies to any one given building in the state of Hawaii on the commercial side.

## Commercial Sector Modeling

In many of our data sources, high-rise (multifamily, 20 units or greater) building profiles are grouped into the commercial sector. Therefore, a majority of the high-rise data points used in this study are estimated using the methodology for the commercial sector (i.e., averaging data collected in the 2009 building survey [BAH 2009a] with the 1994 HECO study [HECO 1994]). However, as high-rise buildings share more key components with residential buildings than with their commercial counterparts in terms of appliance saturation and mix, we have classified them as residential overall, and aggregated them using residential data in the post-profile modeling stage of this analysis.

On the office building side of things, one of our major data points, the 2004 HECO DSM study, contains data for large and small offices. With this to build upon, we have developed subbuilding profiles for large and small offices within the "Office" category, but to maintain continuity with our building stock map (Figure 4. 2007 electricity use in the state of Hawaii [MWh]), we re-aggregate these values in the final projections analysis. We do this because the building map results do not distinguish between large and small offices, therefore making it impossible to derive the number of large and small offices while maintaining consistency in the methodology for scaling up across building types.

### *Commercial Cooling*

#### *Baseline Building*

We estimate baseline cooling load for commercial buildings, by building type, from three variables: average efficiency (kW/ton), average size (tons) and average cooling operating hours (**Table 3**).

- Average cooling operating hours, by building type, are equal to the average values from the 1994 study (HECO 1994) and the 2009 survey (BAH 2009a). For hospitality, average cooling hours are reduced to 70.4% of their total to reflect the average occupancy rate in 2008 (DBEDT 2008), thus adjusting for reduced usage in unoccupied rooms.
- Average efficiencies, by building type, are equal to the average of values from the HECO 2004 study baseline building profiles (HECO 2004) and the 2009 survey (BAH 2009a). Where values are reported as energy efficiency ratio (EER), they are converted to kW/ton by dividing them by 12.
- Average system size is calculated by dividing average building size by average square footage per ton of cooling.
- Average building sizes are equal to the 2004 study's (HECO 2004) assumptions for average building size.
- Average square footage per ton of cooling is derived from averaging 1994 (HECO 1994) values with 2009 survey results (BAH 2009a). 1994 values are back-calculated from total building type square footage, total building type cooling electricity sales, and average operating hours per year.

Since the 2004 study (HECO 2004) does not include model results for high-rises, we make a number of assumptions for high-rises where the calculations require 2004 values.

- Building size: Assuming the maximum number of floors is 47 and the minimum number is 2, the average floors per building is 24.5. Average area per floor is derived from the 2009 survey results and is equal to 18,727 square feet (SF) per floor (BAH 2009a). This value is scaled up to equate to 458,823 SF per building.
- Average operating hours per year: This value is assumed to be equivalent to the hospitality building type.
- Average efficiency: This value is assumed to equal the average of the 2004 value for multifamily units (HECO 2004) and the 2009 survey result for hospitality (BAH 2009a).

**Table 3. Baseline Commercial Cooling Assumptions**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Average Building Area (SF) | 330,00 | 10,000 | 50,000 | 404,700 | 458,823 |
| Average Cooling Operating Hours Per Year | 3,159 | 3,159 | 4,088 | 6,150 | 8,736 |
| Average Efficiency (kW/Ton) | 0.75 | 1.34 | 1.3 | 1.33 | 1.33 |
| Average Cooling Size (Tons) | 921.8 | 19.7 | 76.5 | 300.6 | 189.2 |
| Average Cooling Consumption (kWh/year) | 2,169,352 | 83,723 | 406,532 | 2,464,331 | 2,202,990 |

### *Efficient Building*

The efficient building case predicts average cooling load when average cooling efficiency is improved, given assumptions from the baseline building profiles for average operating hours, average cooling system size, and average building area. By building type, efficiency values for kW/ton are derived from an average of FEMP values (FEMP 2010). The baseline building efficiency values represent average efficiencies from several different system types; thus the efficient building cooling efficiency values are represented by an average of different system types: commercial unitary air-conditioners, air-cooled chillers, packaged units and room AC units. For the large office building type, we assume the efficient system is a water-cooled chiller, which is an upgrade over the mix of centrifugal and less efficient water-cooled chillers prevalent in the base case (**Table 4**).

**Table 4. Efficient Commercial Cooling Assumptions**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Average Efficiency (kW/Ton) | 0.52 | 1.08 | 1.08 | 1.08 | 1.08 |

## ***Commercial Lighting***

### *Baseline Building*

Average lighting load per building, by building type, is equal to the average of existing and new building lighting load profiles from the 2004 HECO building modeling results (HECO 2004).

Number of lamps per building, by lamp type, is derived by averaging 1994 lamp numbers (HECO 1994) and 2009 survey results (BAH 2009a). The 1994 lamp numbers are not reported on a per-building basis. Thus, we calculate 1994 lamps per building by dividing by the total number of lamps estimated in the study by the estimated number of buildings in 1994. Number of buildings in 1994 is back-calculated from the 1994 values for total building area (by building type) and the 2004 study values for average building size (by building type) (HECO 2004). This calculation results in 1994 lamps per building by lamp type and by building type. Next, by building type, 1994 lamp numbers per building by lamp type must be averaged with 2009 lamp numbers per building by lamp type. Since the 1994 and 2009 lamp types are reported in different subcategories, we roll these subcategories into larger categories to take the average (**Table 5**).

**Table 5. Baseline Commercial Lighting Assumptions**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Average Lighting Consumption (kWh/Year) | 1,664,365 | 55,285 | 415,617 | 1,343,157 | 1,522,787 |
| Lamps Per Building (Average Wattage) | | | | | |
| *T12 Fluorescent (82 W)* | 645 | 15 | 479 | 869 | 455 |
| *T8 Fluorescent (57 W)* | 511 | 12 | 37 | 99 | 97 |
| *Incandescent (60 W)* | 33 | 12 | 235 | 2,959 | 1,859 |
| *CFL (17 W)* | 50 | 18 | 6 | 3,189 | 751 |

### *Efficient Building*

To estimate the efficient building lighting scenario, we calculate the expected energy savings from retrofitting all T12 lamps with T8 lamps and all incandescent lamps with CFLs. Energy use per lamp type is calculated for each lamp type, based on average light power (watts) and building type operating hours per year (FEMP 2010). Then, for each building type, the differences in energy use for each replacement (T8s, CFLs, and LED exit signs) are multiplied by the number of retrofits (number of T12s, incandescent lamps, and incandescent exit signs).

## ***Commercial Water Heating***

### *Baseline Building*

The methodology for water heating is similar to the methodology for lighting. Baseline water heating electricity use is the average of 2004 water heating electricity values for new and existing buildings in the 2004 HECO energy model (HECO 2004). Number of water heaters by building type and by water heater type are derived from an average of 2009 survey responses (BAH 2009a) and 1994 water heater numbers (HECO 1994). Similar to lighting, some models of water heaters are not classified in the same way across studies, so they must be combined. For small offices, there are no 1994 or 2009 values for number of water heaters. These values are derived from the number of water heaters in large offices, adjusted by the ratio of average large office size to average small office size (**Table 6**).

Once the average number of water heaters is calculated (per building, by building type) we derive a weighted average energy factor, by building type, as a measure of baseline water heating efficiency. The weighted average is based on figures from the American Council for an Energy-Efficient Economy's (ACEEE's) "Consumer Guide to Home Energy Savings: Condensed Online Version; Water Heating," (ACEEE 2010), in combination with DOE's *EnergySmart Hospitals Training Manual* (ESH 2008), minimum efficiency water heating energy factors, and the number of water heaters per building, by building type. For the purpose of comparing with the efficient water heating case, we multiply the water heating energy loads by the energy factors to obtain measures of the heat energy in the water, net of efficiency losses (**Table 7**).

**Table 6. Baseline Commercial Water Heating Assumptions**

| | **Large Office** | **Small Office** | **Retail** | **Hospitality** | **High-Rises** |
|---|---|---|---|---|---|
| Average Water Heating Electricity Consumption (kWh/Year) | 84,435 | 2,559 | 17,119 | 714,480 | 714,480 |
| Water Heaters Per Building | | | | | |
| *Solar Water Heater* | 0 | 0 | 0 | 0 | 0 |
| *High-Efficiency Electric or Tankless* | 10.9 | 0.3 | 0.2 | 0.4 | 0 |
| *Electric Individual Tank Heaters* | 6.0 | 0.2 | 3.4 | 2.8 | 60.2 |
| *Gas Boilers* | 0 | 0 | 0.83 | 2.9 | 1.2 |
| *Heat Pumps* | 0.1 | 0.002 | 0.2 | 1.34 | 3.1 |
| *Fuel Oil Heaters* | 0 | 0 | 0 | 0.3 | 0 |
| Average Electric Water Heater Energy Factor | 0.87 | 0.87 | 0.82 | 0.96 | 0.86 |
| Average Water Heating Electricity Consumption Adjusted for Losses (kWh/Year) | 73,091 | 2,215 | 14,116 | 684,160 | 611,834 |

**Table 7. Commercial Water Heater Efficiency Values**

| Water Heater Type | Average Energy Factor |
|---|---|
| Tankless/Electric High-Efficiency | 0.9 |
| Electric Tank | 0.79 |
| Gas Storage | 0.6 |
| Heat Pump | 2.2 |
| Fuel Oil | 0.55 |
| Solar Thermal | 1.2 |

### *Efficient Building*

To calculate the efficient water heater energy use per building scenario by building type, we derive energy factors if all existing water heaters are replaced with tankless or high-efficiency water heaters for hospitality and high-rises and with solar water heaters for offices and retail. We assume that solar hot water heaters are not feasible for hospitality and high-rise buildings because the ratio of roof space to building area is too small to support this technology. The energy factor for the efficient building is retabulated with these water heater replacements using the same methodology as for the baseline case. Last, we divide the average water heating electricity load adjusted for losses by the efficient building energy factor to estimate the average efficient building water heating electricity load (**Table 8**).

**Table 8. Efficient Commercial Building Water Heating Electricity Load**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Average Water Heating Electricity Consumption (kWh/Year) | 60,727 | 1,840 | 11,440 | 685,921 | 639,062 |

## ***Commercial Controls***

### *Baseline Building*

Data for the percentage of buildings in Hawaii with EMS and programmable thermostats by building type are available from both the 1994 survey (HECO 1994) and the 2009 survey (BAH 2009a). We average these values to approximate the average percentage of buildings with these systems in the baseline scenario. Data were not available separately for small offices, so we assume that the saturation of controls in this building type is approximately the same as that of the large office building type (**Table 9**).

**Table 9. Saturation of Building Controls, Baseline Case**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Buildings with EMS | 49.7% | 49.7% | 16.4% | 52.2% | 57.9% |
| Programmable Thermostats | 57.5% | 57.5% | 32.5% | 24.3% | 17.6% |
| Adjusted Savings as a Percent of Total Building Electricity Use | 3.9% | 4.3% | 2.3% | 6.7% | 6.2% |

### *Efficient Building*

For the efficient building scenarios, we assume that all buildings will have an EMS and programmable thermostats. Gross electricity savings from installing this equipment are derived from savings per square foot values (**Table 10**) given in the 2004 study building modeling results (HECO 2004). For each building type, the savings values are multiplied by 1 minus the baseline equipment saturations and average square footage per building. Since we are not installing the EMS and programmable thermostats in isolation of other measures, we must reduce the amount of savings from this equipment to avoid double counting savings from lighting and cooling. To avoid double counting savings for each building type, control savings as a percentage of total building energy use (HECO 2004) are reduced by the sum of cooling savings as a percentage of cooling electricity use and lighting savings as a percentage of lighting electricity use (see adjusted values in **Table 10**).

**Table 10. Control Savings**

| | Gross Electricity Savings Per SF (kWh/SF)[15] |
|---|---|
| EMS | 1.44 |
| Programmable Thermostat | 0.68 |

## ***Commercial Fans and Motors***

### *Baseline Building*

In this section, we calculate the number of standard and efficient fans and motors in each baseline building. These numbers are averages of values from the 1994 HECO survey (HECO 1994) and the 2009 survey (BAH 2009a). While results for number of fans and motors per building, by fan and motor type, are available from the 2009 survey, the 1994 survey reports the number of standard-efficiency fans and motors per building and the percentage of buildings with variable-speed fans and efficient motors. To calculate the number of efficient fans and motors per building in 1994, the number of 1994 fans and motors is multiplied by the percentage of buildings with variable-speed fans and efficient motors. Due to missing 1994 fan and motor values for offices, the number of fans and motors in offices is based entirely on 2009 survey

[15] A range of control savings values is available from the 2004 HECO study depending on building type and on whether the building is new construction or existing. We choose conservative values to avoid overestimating savings.

results. Small office fans and motors are scaled down based on the ratio of small office to large office per building areas (**Table 11**).

**Table 11. Baseline Fan and Motor Assumptions (Number of Fans and Motors Per building)**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Standard Fans | 15 | 0.5 | 2.3 | 41.7 | 13.5 |
| Variable-Speed Drive Fans | 29 | 0.9 | 0 | 6 | 0 |
| Standard-Efficiency Motor | 15 | 0.5 | 5.1 | 6.7 | 1.2 |
| Premium-Efficiency Motor | 53.5 | 1.6 | 1 | 9.8 | 10.5 |

*Efficient Building*

We assume that efficient buildings will replace all standard-efficiency fans and motors with variable-speed fans and premium-efficiency motors. Electricity savings from this retrofit are calculated based on a value of electricity savings per fan from the 2004 HECO study (HECO 2004) and on a value of electricity savings per premium-efficiency motor from a 2008 KEMA study (KEMA 2008) (**Table 12**).

**Table 12. Efficient Fan and Motor Assumption**

| | Electricity Savings Per Unit (kWh/Unit) |
|---|---|
| Variable-Speed Fan | 769.8 |
| Premium-Efficiency Motor | 54.8 |

### *Commercial Building Envelope*

*Baseline Building*

There are four components to the building envelope efficiency measures in the model: percentage of buildings with roof insulation (R-19), percentage of buildings with wall insulation (R-13), percentage of buildings with high-reflectivity roofs, and percentage of buildings with efficient windows.[16] The percentages of buildings with roof insulation, by building type, are averages of 1994 survey results (HECO 1994) and 100% (we assume that all buildings on the upper end of the building efficiency curve will have roof insulation). Since we do not have data on wall insulation saturation, we assume that the percentage of buildings with roof insulation is approximately the same as the percentage of buildings with wall insulation.

For high-reflectivity roofs and high-efficiency window saturations, we assume that no buildings on the low end of the efficiency curve will have high-reflectivity roofs or high-efficiency

[16] Hawaii building codes specify at least R-19 building insulation, and we assume virtually no buildings have R-25 insulation (Wigg 2009).

windows and that the upper end of the efficiency curve is represented by responses to the 2009 survey (BAH 2009a) (**Table 13**).

**Table 13. Saturation of Insulation Types for Building Envelope, Baseline Case**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Percentage of Buildings with Roof Insulation | 62.1% | 62.1% | 61% | 60.6% | 66.5% |
| Percentage of Buildings with Wall Insulation | 62.1% | 62.1% | 61% | 60.6% | 66.5% |
| Percentage of Buildings with High-Reflectivity Roofs | 30% | 30% | 40% | 0% | 50% |
| Percentage of Buildings with High-Efficiency Windows | 0% | 0% | 0% | 0% | 50% |

### *Efficient Building*

Building envelope electricity savings are based on retrofitting the buildings with no ceiling insulation to R-19 ceiling insulation (we assume no buildings will upgrade to higher than R-19 insulation, as R-19 is the current Hawaii building code level), R-13 to R-19 wall insulation, high-reflectivity roofs, and high-efficiency windows (**Table 14**). We assume buildings with R-13 wall insulation will upgrade to R-19 wall insulation, and buildings without wall insulation will not install wall insulation (we assume that most of the buildings without wall insulation are not cooled, so no electricity savings would result from increasing insulation).

- *Ceiling insulation savings*—These values are based on kWh savings per SF of roof area for small offices retrofitting from no insulation to R-19 (HECO 2004). These savings are multiplied by the percentage of buildings without insulation by building type (HECO 2004) and by average floor space per story (assuming this is equivalent to roof area).
- *Wall insulation savings*—The electricity savings due to upgrading from R-13 to R-19 insulation are based on kWh savings per SF of exterior wall area for small offices (HECO 2004).[17] This value is multiplied by estimated exterior wall area for each building type and by the percentage of buildings with R-13 wall insulation.

[17] We assume the average wall is 9' in height for the calculation of exterior wall area per building.

- *High-reflectivity savings*—High-reflectivity roofs save 18.6% of a building's cooling energy on average (EPA 2004). We apply this percentage to the baseline percentage of buildings without high-reflectivity roofs. To adjust for the effect of a building's ratio of roof to building area, we multiply savings by the ratio of roof to total building area. Percentage savings from roof upgrades will be less for taller buildings, with the roof as less of a percentage of the building envelope.
- *High-efficiency windows savings*—By building type, we multiply savings per square foot of window (from upgrading to double-pane windows (HECO 2004)[18]) by the average window square footage per building. We use a window-to-wall ratio from the 2004 study to derive window square footage based on our previous calculation of exterior wall area. We also assume that the average high-rise window-to-wall ratio is similar to that of an average hospitality building, since the window-to-wall ratio is not available in the 2004 study.
- All of the building envelope electricity savings are summed, and then we subtract cooling savings as a percentage of total building energy use to prevent double counting as we upgrade both building systems in the efficient building profile.

**Table 14. Efficient Commercial Building Envelope Assumptions**

| | **Electricity Savings Assumption** |
|---|---|
| Installing Ceiling Insulation (No Insulation to R-19) | 2.24 kWh Per SF of Roof |
| Installing Wall Insulation (R-13 to R-19) | 0.038 kWh Per SF of Wall |
| Installing a High-Reflectivity Roof | 18.6% Cooling Energy Savings |
| Installing High-Efficiency Windows | 4 kWh Per SF of Window |

### *Commercial Computers and Data Centers*

#### *Baseline Building*

For computers and data centers, we estimate the number of standard efficiency computers, ENERGY STAR computers, standard data centers, and efficient data centers. We average values from the 1994 HECO study (HECO 1994) and a 2009 commercial sector survey (BAH 2009a) for all of these estimates. We assume that the number of ENERGY STAR computers at the low end of the efficiency curve is zero. All data centers reported in the studies are also assumed to be standard efficiency 1-U servers (**Table 15**).[19]

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[18] We understand that additional U-value improvements could be made through the adoption of window film as opposed to double-paned glass in this case. However, given our data at hand, and the fact that main improvement in this area would be in reduced cost, rather than reduced savings and that cost is to be examined more closely at a programmatic level, we have opted to use double-paned glass as a proxy for window improvement for the purposes of this study.

[19] The 1994 study reports number of "mainframes" and we assume this is roughly equivalent to today's data center for the purposes of this study.

**Table 15. Baseline Commercial Computer and Data Center Assumptions**

| | Large Office | Small Office | Retail | Hospitality | High-Rises |
|---|---|---|---|---|---|
| Standard Computers Per Building | 37 | 1.1 | 15.2 | 54 | 15.2 |
| ENERGY STAR Computers Per Building | 1.5 | 0.1 | 0.2 | 100 | 3 |
| Data Centers Per Building | 1.1 | 0.1 | 0.3 | 0.5 | 0.5 |

*Efficient Building*

Savings for upgrading to ENERGY STAR computers and monitors are based on savings estimates in the 2004 HECO modeling results (HECO 2004). Savings from data centers are based on an estimate by Rocky Mountain Institute (RMI 2008) (**Table 16**).

**Table 16. Efficient Commercial Computer and Data Center Assumptions**

| | Electricity Savings Per Unit (kWh/Unit) |
|---|---|
| ENERGY STAR Computer | 84 |
| ENERGY STAR Monitor | 197 |
| Efficient Data Center | 534 |

## Residential Sector Modeling

For most single family and multifamily building technology types in the model, baseline energy use and saturations are based on the 2008 HECO Residential Appliance Survey (HECO 2009b). Appliance saturations are listed by utility (HECO, MECO, or HELCO), so we combine these values by weighting them according to the percentage of the utility's contribution to total state electricity use. Energy use per appliance/system type is multiplied by its saturation to derive average energy use by end use and building type. Multifamily cooling and water heating appliance energy uses are reduced, relative to the values for single family buildings, by the percentage difference between the 2004 study's modeling results for each respective end use (HECO 2004). Below, we describe these assumptions in more detail and note adjustments and exceptions.

Since multifamily energy use is calculated on a per-housing-unit level, we multiply this value by the average housing units per building to derive the average energy use per building. To estimate average housing units per building, we calculate the weighted average units per building from the distribution of energy use per housing type (BAH 2009b). In the distribution, energy use is broken down by housing type, and these housing types are categorized by number of units per building (2, 3, or 4; 5 to 9; and 10 to 19).

### *Residential Refrigeration*

*Baseline Building*

The baseline building refrigeration assumptions are estimated by multiplying appliance saturations with unit energy use, as described above. **Table 17**, below, outlines the base assumptions used in calculating the baseline residential refrigeration use.

**Table 17. Baseline Residential Refrigeration Assumptions**

| | **Single Family** | **Multifamily (<20 Units Per Building, Per Unit Assumptions)** |
|---|---|---|
| First Refrigerator Saturation | 100% | 100% |
| First Refrigerator Average Energy Use (kWh/Year) | 661 | 661 |
| Second Refrigerator Saturation | 50% | 13% |
| Second Refrigerator Average Energy Use (kWh/Year) | 1,979 | 1,979 |
| Freezer Saturation | 31% | 14% |
| Freezer Average Energy Use (kWh) | 563 | 563 |

*Efficient Building*

For both single family and multifamily efficient building profiles, energy savings per refrigerator and freezer are subtracted from the standard energy use values. These energy savings per efficient refrigerator values are estimated using modeling results from the 2004 HECO study for upgrading from a minimum NAECA efficiency refrigerator to an ENERGY STAR refrigerator (HECO 2004). Energy savings per efficient freezer is derived from FEMP efficient freezer values (FEMP 2010) (**Table 18**).

**Table 18. Efficient Residential Building Refrigeration Assumptions**

| | **Single Family** | **Multifamily (<20 Units Per Building, Per Unit Assumptions)** |
|---|---|---|
| First Refrigerator Saturation | 100% | 100% |
| First Refrigerator Average Energy Use (kWh/Year) | 558 | 558 |
| Second Refrigerator Saturation | 50% | 13% |
| Second Refrigerator Average Energy Use (kWh/Year) | 1,666 | 1,666 |
| Freezer Saturation | 31% | 14% |
| Freezer Average Energy Use (kWh/Year) | 350 | 350 |

### ***Residential Cooling***

*Baseline Building*

Appliance saturations and energy use values are estimated as described above. The data only list energy use values for central air-conditioning (AC), so we assume that packaged central AC and split central AC systems use a similar amount of electricity per year **(Table 19).** The efficiency values for each system type are not used in calculating energy use, as energy use per efficient unit is given. The efficiency value for room AC is an estimate used in the 2004 HECO study (HECO 2004). For central AC units, we derive efficiency from a FEMP example central AC unit (FEMP 2010). We scale the efficiency of our model central AC unit according to the energy use and efficiency of this example central AC unit.

**Table 19. Baseline Residential Building Cooling Assumptions**

| | **Single Family** | **Multifamily (<20 Units per Building, Per Unit Assumptions)** |
|---|---|---|
| Room AC Saturation | 29% | 35% |
| Room AC Average Efficiency (EER) | 8.6 | 8.6 |
| Room AC Average Energy Use (kWh/Year) | 1,397 | 652 |
| Packaged Central AC Saturation | 11% | 9% |
| Packaged Central AC Average Efficiency (Seasonal Energy Efficiency Rating [SEER]) | 13 | 13 |
| Packaged Central AC Average Energy Use (kWh/Year) | 3,750 | 2,394 |
| Split AC Saturation | 19% | 6% |
| Split AC Average Efficiency (SEER) | 13 | 13 |
| Split AC Average Energy Use (kWh/Year) | 3,750 | 2,394 |

*Efficient Building*

Energy efficiency estimates for the efficient building profile cooling systems are based on minimum FEMP purchasing requirements (FEMP 2010). We adjust these efficiencies to correspond to energy saving values from the 2004 HECO modeling results (HECO 2004). For example, the minimum FEMP purchasing requirement for residential room AC units is 10.7 EER, but we only have energy savings values for improving efficiency from 8.6 to 10.2. Therefore, we set the efficient building profile cooling efficiency at 10.2 (**Table 20**).

**Table 20. Efficient Residential Building Cooling Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Room AC Saturation | 29% | 35% |
| Room AC Average Efficiency (EER) | 10.2 | 10.2 |
| Room AC Average Energy Use (kWh/Year) | 1,001 | 443 |
| Packaged Central AC Saturation | 11% | 9% |
| Packaged Central AC Average Efficiency (SEER) | 18 | 18 |
| Packaged Central AC Average Energy Use (kWh/Year) | 3,361 | 2,247 |
| Split AC Saturation | 19% | 6% |
| Split AC Average Efficiency (SEER) | 18 | 18 |
| Split AC Average Energy Use (kWh/Year) | 3,361 | 2,247 |

### *Residential Lighting*

#### *Baseline Building*

Baseline residential lighting energy use is calculated using a sample distribution of the number of lights per building by lamp type (HECO 2009a). Average lamp number estimates are weighted averages from the distribution. Lighting electricity use per building is calculated by multiplying average lamp numbers by their average power and an estimate of average residential lighting operating hours (1,200 per year) (FEMP 2010) (**Table 21**).

**Table 21. Baseline Residential Lighting Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Average Number of Lamps Per Building (Average Wattage) | | |
| *Incandescent (40 W)* | 16.4 | 10.8 |
| *CFL (17 W)* | 9.0 | 5.2 |
| *T12 Tube Fluorescent (47 W)* | 5.9 | 2.9 |
| *Spot Light (100 W)* | 2.3 | 1.0 |
| *Outdoor Light (100 W)* | 3.4 | 1.3 |
| Average Operating Hours | 1,200 | 1,200 |

#### *Efficient Building*

For the efficient building profiles, all incandescent lights are replaced with CFLs, all T12 tube fluorescent lights are replaced with T8 fluorescent lights, and both spot and outdoor lights are replaced with CFLs of the appropriate wattage. Average total lighting energy use is estimated using the same methodology as for the baseline profile (**Table 22**).

**Table 22. Efficient Residential Lighting Assumptions (Average Number of Lamps Per Building)**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Incandescent (40 W) | 0 | 0 |
| CFL (17 W) | 25.4 | 15.9 |
| T8 Tube Fluorescent (45.5 W) | 5.9 | 2.9 |
| Efficient Spot Light (27 W) | 2.3 | 1.0 |
| Efficient Outdoor Light (27 W) | 3.4 | 1.3 |

## *Residential Water Heating*

### *Baseline Building*

To estimate average per-building water heating energy use, we use the 2008 survey's electric water heater saturation and energy use (HECO 2009b). The 2008 survey does not specify the type of electric water heater corresponding to the saturation or the efficient water heaters in the baseline. We assume that the electric water heater in the 2008 study is a standard efficiency electric storage water heater (**Table 23**).

**Table 23. Baseline Residential Water Heating Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Standard Electric Storage WH Saturation | 57% | 61% |
| Standard[20] Electric Storage WH Average Energy Use (kWh/Year) | 2,719 | 1,941 |
| Solar WH Saturation | 28% | 0% |
| Solar WH Average Energy Use (kWh/Year) | 644 | 460 |
| High-Efficiency[18]Electric Resistance WH Saturation | 0% | 10% |
| High-Efficiency Electric Resistance WH Energy Use (kWh/Year) | 2,462 | 1,758 |

### *Efficient Building*

For the efficient case water heaters, we assume efficient water heater types based on those offered by the HECO Residential Water Heating Program and Residential New Construction Program (KEMA 2008). In the model, single family buildings with water heating upgrade to

[20] Our calculations do not use water heater efficiency values to calculate energy savings, only energy use. We compare the annual energy use of an average Hawaii water heater to the energy use of solar water heaters in the efficient case to reduce the need to forecast future water usage patterns per person.

solar water heaters, and multifamily buildings with water heating upgrade to high-efficiency electric water heaters (**Table 24**).[21] We assume no multifamily buildings will use solar water heaters due to feasibility issues for buildings with multiple stories, multiple units, and limited roof space. Energy use for the efficient technologies is calculated based on the average per unit impact of the technologies (KEMA 2008).

**Table 24. Efficient Residential Water Heating Assumptions**

| | Single Family | Multi Family (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Standard Electric Storage WH Saturation | 0% | 0% |
| Solar WH Saturation | 84% | 0% |
| High-Efficiency Electric Resistance WH Saturation | 0% | 71% |

### *Residential Building Envelope*

#### *Baseline Building*

The percentage of single family and multifamily buildings with wall insulation and ceiling insulation are derived from data collected by HECO (HECO 2009b). We assume that the baseline wall insulation is R-13 and the baseline and ceiling insulation is R-19 (**Table 25**). These levels of insulation are the current Hawaii building code (Wigg 2009).

**Table 25. Baseline Residential Building Envelope Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Percentage of Buildings with R-13 Wall Insulation | 20.4% | 14.1% |
| Percentage of Buildings with R-19 Ceiling Insulation | 21.1% | 13.1% |

#### *Efficient Building*

In the model, we calculate electricity savings from buildings with the baseline level of wall insulation that will upgrade to R-19 insulation and from buildings without the baseline R-19 ceiling insulation that will upgrade to this baseline level. We do not calculate savings from upgrading wall insulation to multifamily homes because this efficiency measure is likely too costly for existing multifamily buildings (**Table 26**).

- For ceiling insulation upgrades, we calculate electricity savings from only those buildings without insulation and with cooling. There will be no electricity savings for buildings

[21] The study does not derive the efficiency of "high-efficiency electric water heaters." Average per-unit impact, as defined in the KEMA 2008 DSM report, is used to derive the average energy use of this technology in the efficient case.

without cooling that install insulation. To calculate this percentage, we subtract the percentage of buildings with ceiling insulation from the total percentage of buildings with cooling.[22] This percentage is multiplied by an estimate of roof area and an estimate for electricity savings per square foot of R-19 insulation installed.

- To estimate the electricity savings from the percentage of buildings that will upgrade from R-13 to R-19 wall insulation, we multiply the percentage of buildings with insulation by average exterior wall area per building and by electricity savings per square foot of exterior wall area.
- All of the building envelope electricity savings are summed and then we subtract cooling savings as a percentage of total building energy use to prevent double counting as we upgrade both building systems in the efficient building profile.

**Table 26. Efficient Residential Building Envelope Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Average Exterior Wall Area Per Building (SF) | 1,704 | 6,814 |
| Average Roof Area Per Building (SF) | 995 | 1,184 |
| Electricity Savings Per Square Foot of Installed R-19 Wall Insulation (kWh/Year) | 0.012 | 0 |
| Electricity Savings Per Square Foot of Installed R-19 Ceiling Insulation (kWh/Year) | 0.44 | 1.1 |

### *Residential Appliances*

#### *Baseline Building*

To calculate baseline energy use and saturation of dishwashers, clothes washers, clothes dryers and ranges/ovens, we use values from the 2008 saturation study (HECO 2009b) with some adjustments. First, the 2008 saturation study value for dishwasher energy use is higher than the 2004 HECO study value. We assume that the higher dishwasher values include the energy needed to heat water. Since we are counting this electricity in the water heater section, we use the lower 2004 HECO study value as the amount of electricity used by the dishwasher. Second, the energy use value for clothes washers is omitted from the 2008 data. Again, we use a 2004 HECO study value for the energy used by the average clothes washer motor (**Table 27**).

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[22] Total % buildings with insulation (TI) = % buildings with cooling, with insulation (CI) + % buildings without cooling with insulation (NCI); Total % buildings with cooling (TC) = % buildings with cooling without insulation (CNI) + % buildings with cooling with insulation (CI).

To derive CNI: assume NCI = 0; CI = TI; CNI = TC – TI (substituting TI for CI). This methodology is slightly different from that used for commercial buildings, as we account for commercial buildings without cooling using average tons of cooling per SF, not saturation of buildings with cooling.

**Table 27. Baseline Residential Appliance Assumptions**

| | Single Family | Multifamily (<20 Units Per Building, Per Unit Assumptions) |
|---|---|---|
| Dishwasher Saturation | 40% | 39% |
| Dishwasher Average Energy Use (kWh/Year) | 179 | 179 |
| Electric Cooking Saturation | 87% | 92% |
| Electric Cooking Energy Use (kWh/Year) | 663 | 663 |
| Clothes Washer Saturation | 97% | 71% |
| Clothes Washer Energy Use (kWh/Year) | 103 | 103 |
| Clothes Dryer Saturation | 74% | 59% |
| Clothes Dryer Energy Use kWh/Year) | 354 | 354 |

*Efficient Building*

Energy savings values for each appliance are derived from either the HECO 2004 (HECO 2004) study's modeling results or FEMP minimum appliance efficiency requirements (FEMP 2010). Dishwasher savings are equal to the savings from going from a standard dishwasher to an NAECA minimum required efficiency dishwasher. Standard efficiency ovens are replaced by ENERGY STAR ovens. For clothes washers, we estimate that the electricity used by the motor is 10% of total energy use (the value for total energy use, including energy to heat water, is listed in FEMP's purchasing guidelines). The FEMP required minimum efficiency clothes washer model uses 750 kWh per year, so we assume that its motor will use 75 kWh per year. Dryer savings are values from the 2004 HECO modeling results (**Table 28**).

**Table 28. Efficient Residential Appliance Assumptions**

| | **Single Family** | **Multifamily (<20 Units Per Building, Per Unit Assumptions)** |
|---|---|---|
| Dishwasher Average Energy Use (kWh/Year) | 20 | 20 |
| Electric Cooking Energy Use (kWh/Year) | 546 | 546 |
| Clothes Washer Energy Use (kWh/Year) | 75 | 75 |
| Clothes Dryer Energy Use (kWh/Year) | 188 | 188 |

## Appendix II: "Hawaii Building Stock Mapping and the Way Forward" (Booz Allen Hamilton, April 22, 2009)

In April of 2009, Booz Allen Hamilton (BAH) began the process of evaluating the energy efficiency potential of the Hawaii existing building stock by creating a roadmap of the energy demand in the state. This process involved several different data sources for both the residential and commercial sectors, which will be outlined in this appendix. Primary data sources on the residential side include the 2000 U.S. Census and the U.S. DOE's Energy Information Administration (EIA), while on the commercial side sources included data provided by the Hawaii state utilities: Hawaiian Electric Company (HECO), Hawaii Electric Light Company (HELCO), Maui Electric Company (MECO), and Kauai Island Utility Cooperative (KIUC). This analysis was presented to the Hawaii Clean Energy Initiative (HCEI) Energy Efficiency working group at its April, 2009 meetings.

### Residential

On the residential side of the analysis, BAH began by gathering all the information available on the number and types of housing units in the state (Census, 2000b). This data was combined with the unit energy consumption (UEC data from HECO 2009b; where data was missing, it was supplemented with values from HECO 2004) for each housing type, by island, to create the table of demand for the year 2000, when the census data was collected (**Table 29**).

**Table 29. Residential Electricity Demand, by Island (2000)**

| Residential Elect Demand (2000), MWh | Oahu | Hawaii | Maui | Kauai | Total |
|---|---|---|---|---|---|
| Housing: 1-Unit, Detached | 902,314 | 306,749 | 200,931 | 106,956 | 1,516,951 |
| Housing: 1-Unit, Attached | 198,043 | 13,140 | 22,241 | 9,378 | 242,802 |
| Housing: 2 Units | 45,583 | 9,661 | 6,589 | 5,460 | 67,293 |
| Housing: 3 or 4 Units | 91,190 | 9,196 | 10,218 | 4,866 | 115,470 |
| Housing: 5 to 9 Units | 127,976 | 12,216 | 23,532 | 6,765 | 170,488 |
| Housing: 10 to 19 Units | 94,022 | 11,040 | 16,163 | 4,907 | 126,132 |
| Housing: 20 or More Units | 432,862 | 25,348 | 61,040 | 9,071 | 528,321 |

Once the relative energy demand was known, a table of factors was derived outlining the ratio of electricity usage for the subsectors within residential (**Table 30**). These factors were then applied to the EIA 2007 Hawaii residential electricity demand to generate the end usage numbers for the residential sector, by subsector, adjusted to 2007 demand levels (**Table 31**).

**Table 30. EIA Electricity Demand, by Sector (2007)**

| Sector | EIA Demand (2007), MWh |
|---|---|
| Commercial & Industrial | 6,677,905 |
| Residential | 3,182,000 |
| *Total* | 9,859,905 |

**Table 31. Residential Energy Demand Allocation (Base Year) and 2007 Demand Levels**

| | % of Total Residential Demand, Base Year (2000) | 2007 Subsector Demand (MWh) |
|---|---|---|
| Housing: 1-Unit, Detached | 55% | 1,744,178 |
| Housing: 1-Unit, Attached | 9% | 279,172 |
| Housing: 2 Units | 2% | 77,373 |
| Housing: 3 or 4 Units | 4% | 132,767 |
| Housing: 5 to 9 Units | 6% | 196,026 |
| Housing: 10 to 19 Units | 5% | 145,025 |
| Housing: 20 or More Units | 19% | 607,459 |
| *Total* | 100% | 3,182,000 |

## Commercial

On the commercial side, BAH began by collecting the last full year of recorded commercial electricity demand data (by sector) from the four major utility companies in Hawaii: HECO (2007), HELCO (2005), MECO (2005) and KIUC (2008). HECO and KIUC provided their billed MWh figures directly to BAH, while HELCO's and MECO's numbers were drawn from their most recent Integrated Resource Plans (IRPs) (HELCO 2007, MECO 2007). As this data tended to span a range of years from 2005 through 2008 (due to the cyclical nature of the IRP process), BAH harmonized it by converting it to a common year's value. This was done by utilizing the relative allocations of electricity demand provided by the utilities, by island, and applying them to the total electricity demand for the year 2007 as recorded by the EIA (**Table 30**, above) This allowed BAH to maintain a common year across all utilities, while at the same time reflecting island-specific variances in electricity demand. The demand factors identified by the utilities are provided in **Table 32**, while the EIA total and the relative distributions for the year 2007 calculated from these factors are provided in (**Table 33**).

**Table 32. Commercial Electricity Demand Allocation by Sector and Island (% of Total Commercial Demand, Base Year)**

| Commercial | Oahu (2007) | Hawaii (2004) | Maui (2003) | Kauai (2008) |
|---|---|---|---|---|
| Office/Business Services | 16% | 6% | 8% | 25% |
| Hotel | 8% | 17% | 24% | 26% |
| Health | 5% | 3% | 3% | 4% |
| Education | 8% | 10% | 4% | 0% |
| Air Facility/Transport | 2% | 2% | 2% | 4% |
| Manufacturing/Food Processing/ Farming | 4% | 5% | 1% | 2% |
| Services/Recreational/Amusement | 8% | 12% | 9% | 9% |
| Restaurant | 5% | 5% | 6% | 5% |
| Retail/Warehouse | 16% | 21% | 24% | 18% |
| Water Pumping | 4% | 17% | 11% | 0% |
| Military | 23% | 1% | 1% | 5% |
| Other | 0% | 1% | 7% | 2% |

**Table 33. Commercial Electricity Demand by Sector and Island (2007)**

| Commercial (MWh) | Oahu | Hawaii | Maui | Kauai | Total |
|---|---|---|---|---|---|
| Office/Business Services | 820,000 | 39,095 | 60,979 | 73,231 | 993,305 |
| Hotel | 400,000 | 113,934 | 174,806 | 74,894 | 763,634 |
| Health | 231,000 | 22,340 | 22,133 | 10,214 | 285,687 |
| Education | 402,000 | 63,669 | 29,247 | 791 | 495,708 |
| Air Facility/Transport | 122,000 | 10,053 | 12,760 | 11,139 | 155,953 |
| Manufacturing/Food Processing/Farming | 193,000 | 35,744 | 4,630 | 5,075 | 238,449 |
| Services/Recreational/ Amusement | 382,000 | 80,424 | 67,641 | 24,529 | 554,594 |
| Restaurant | 257,000 | 34,627 | 46,863 | 14,546 | 353,036 |
| Retail/Warehouse | 814,000 | 139,625 | 172,434 | 51,705 | 1,177,764 |
| Water Pumping | 210,000 | 111,700 | 81,192 | - | 402,892 |
| Military | 1,167,000 | 4,468 | 5,646 | 15,374 | 1,192,488 |
| Other | - | 5,585 | 52,735 | 6,076 | 64,397 |
| Total | 4,998,000 | 661,264 | 731,066 | 287,574 | 6,677,905 |

### Combined

Once the data for the commercial and residential sectors was harmonized to 2007 levels, it was aggregated to form **Figure 15**, below (same as **Figure 4** in the main body of the report). This data was used to prioritize the key sectors of existing demand for Hawaii to focus on in its attempt to reduce its electricity usage by 4,300 GWh in the year 2030 (noncumulative). This also forms the basis for the six existing building profiles developed in this report, as the top six sectors by demand are where BAH focused its modeling efforts to begin.

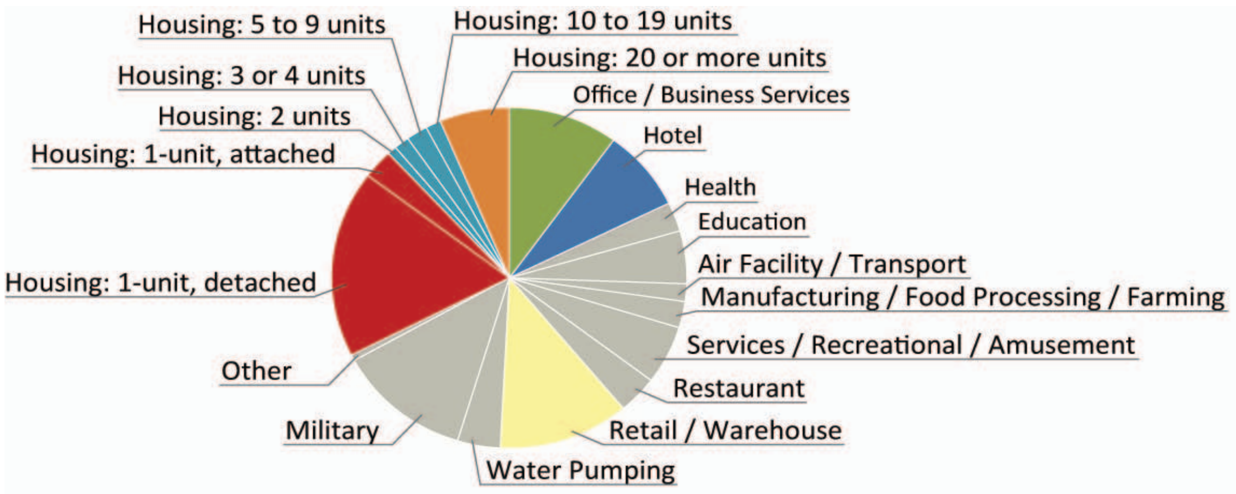


**Figure 15. 2007 Electricity use in the state of Hawaii (MWh)**

# REPORT DOCUMENTATION PAGE

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**14. ABSTRACT** *(Maximum 200 Words)*
In June 2009, the State of Hawaii enacted an Energy Efficiency Portfolio Standard (EEPS) with a target of 4,300 gigawatt hours (GWh) by 2030 (Hawaii 2009). Upon setting this goal, the Hawaii Clean Energy Initiative, Booz Allen Hamilton (BAH), and the National Renewable Energy Laboratory (NREL), working with select local stakeholders, partnered to execute the first key step toward attaining the EEPS goal: the creation of a high-resolution roadmap outlining key areas of potential electricity savings. This roadmap was divided into two core elements: savings from new construction and savings from existing buildings. BAH focused primarily on the existing building analysis, while NREL focused on new construction forecasting. This report presents the results of the Booz Allen Hamilton study on the existing building stock of Hawaii, along with conclusions on the key drivers of potential energy efficiency savings and on the steps necessary to attain them.

**15. SUBJECT TERMS**
Hawaii; Hawaii Clean Energy Initiative; HCEI; Energy Efficiency Portfolio Standard; EEPS; energy efficiency; energy savings; new construction; existing buildings; Building Efficiency

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