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# Roles of income, price and household size on residential electricity consumption: Comparison of Hawaii with similar climate zone states

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ABSTRACT

In general, it is expected that residential electricity consumption decreases due to price increase. However, electricity consumption can also increase while electricity price increases, provided that income increases at the same rate or higher. Thus, we investigated the factors affecting residential electricity consumption in Hawaii; particular emphasis was placed on the Island of Oahu, most populated and an urban island. We determined that the average residential electricity consumption decreased by over 25% between the peak usage of 2004 and 2012. Despite a decrease in residential electricity consumption, the ratio of the average electricity bill to per capita income increased from 3% to 5%. A comparison of the islands' residential energy usage suggests that each island has its own electricity consumption behavior, suggesting the importance of dwelling type, life style and household size. Further comparison of the residential electricity consumption of Hawaii with Arizona, California, Florida and Texas suggests that there is a general decrease in residential electricity consumption. However, unlike Hawaii, reduction in residential electricity usage translates into cost savings in other states. The results suggest that the decrease in residential electricity consumption in Hawaii is simply because people cannot afford it.

Linear regression analysis indicates that household size is an important variable in determining the residential electricity consumption in Oahu, however is not a determining factor in other islands. It was also observed that unlike Oahu, income and price alone are not good indicators of residential electricity consumption for the islands of Hawaii, Maui and Kauai.



## 1. Introduction

Generally, residential electricity usage varies with the household size (HHS), type and size of the residential dwelling, climate, ownership of appliances and other factors (Yohanis, 2012). Furthermore, researchers have shown that residential electricity consumption varies with income and electricity price. For example, some researchers (Dergiades and Tsoulfidis, 2008) reported that consumption is very sensitive to price in the long run, whereas other studies based on State level panel data (Sanquist et al., 2012; Alberini and Filippini, 2011) reported that consumption is relatively insensitive to price, especially in the short term.

Recently, the interest in residential electricity consumption has been renewed because of introduced energy efficiency and conservation incentives with an increased awareness of global warming. The intent of all energy incentives is to reduce electricity consumption, which in turn reduces associated carbon emissions. Reduction of energy consumption can be organized into four different categories:

(i) **Increased Efficiency:** Energy consumption is reduced due to the adoption of energy efficiency technologies such as LED bulbs or a refrigerator with a higher coefficient of performance. Installation of efficient appliances and lighting do not require residents' active participation to reduce energy consumption. However, without active participation of residents in energy conservation activities, new energy efficient technologies may increase the overall usage of these appliances and lighting because they are now less expensive to operate. Economists call this the "rebound effect"; when electricity consumption increases with energy efficiency improvements or increased income. The rebound occurs because of increased purchasing power. Based on historical data, Tsao et al. (2010) stated that a net increase of electricity prices by 12% will cause a reduction in electricity usage for lighting by 2030. Furthermore, Ghosh and Blackhurst (2014) found a negative correlation between energy efficiency and energy savings.

(ii) **Building Codes:** States mandate strict energy codes for newly built or renovated dwellings to meet certain energy

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requirements. Several researchers studied the effect of introducing building codes on residential electricity demand. For example, Aroonruengsawat et al. (2009) reported that the introduction of building codes decreased energy consumption from 0.3% to 5% per capita depending on the state. Similarly, Jacobsen and Kitchen (2013) reported that building codes reduced electricity consumption by 4% in Florida. Furthermore, Koirala et al. (2013) stated that the application of energy efficiency building codes IECC 2003 and IECC 2006 can save about 1.8% on residential electricity consumption. Levinson (2014) used energy usage data from buildings in California and reported that "*there is very little evidence that buildings constructed more recently in California are using less electricity*". Chong (2012) reported that new buildings use more electricity than vintage buildings. He further reported that new buildings are more responsive to high temperatures in Southern California. Chong (2012) predicted that residential electricity consumption will increase in new buildings.

The cited studies suggest that the effect of the building energy codes on residential electricity demand is inconclusive. Many factors can be attributed to the inconclusive results. For example, new buildings are larger in size and have several accessories such as air conditioning, pools and other equipment. Older buildings might not have such amenities and therefore may have a lower rate of energy consumption. At the same time, new houses may be occupied by a younger generation that is less susceptible or willing to take measures to reduce electricity consumption (Jones et al., 2015; Mc Loughlin et al., 2012; Yohanis et al., 2008).

(iii) **Implementation of Energy Conservation Measures:** Energy demand reduction is realized by eliminating the "waste", such as turning off the lights in an unoccupied rooms, placing the water heating pump on a timer so that it will not respond unnecessarily to temperature fluctuations during the day when no one is at home, or placing the air conditioning on a timer. Implementation of these types of energy conservation measures requires behavior changes.

Researchers report that feedback on household electricity consumption leads to a decrease in electricity consumption (Fischer, 2008; Allcott, 2011; Ayers et al., 2009). However, Allcott and Rogers (2012) report that feedback related energy conservation leads to "quick action with fast slide back" behavior. Thus, the long term or residual feedback associated with energy conservation measure related energy savings needs to be further investigated.

(iv) **Eliminating Energy Usage:** This type of energy reduction is realized by residents' active participation. For example, if residents stop using the pool, spa or the clothes dryer at home, they will reduce their electricity consumption. Brown and Koomey (2003) reported that the electricity consumption of pools and spas contributed to 2% of residential electricity usage. They also reported that dryers account for 2% of the residential electricity usage in California. Thus, the preference of air drying washed clothes would surely reduce residential electricity consumption.

With rises in oil prices and a recession in 2008, almost all States in the US introduced/enhanced energy incentives programs to reduce energy consumption. Similarly, the State of Hawaii introduced the Hawaii Clean Energy Initiative (HCEI) program in 2008. The introduced HCEI program originally called for 70% renewable energy generation by 2030. After publication of our paper entitled "Conservation vs. renewable energy: Case studies from Hawaii" in 2009 (Yalcintas and Kaya, 2009), HCEI revised its goal of 40% renewable energy and a 30% reduction in energy usage due to energy efficiency by 2030.

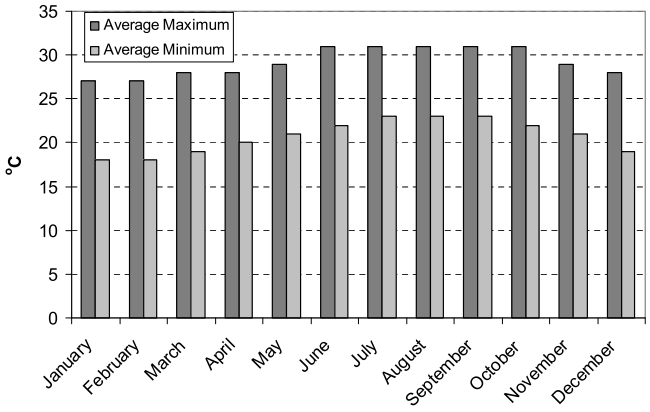


**Fig. 1.** Typical average monthly maximum and minimum temperatures in Oahu, Hawaii.

Numerous researchers have investigated the effect of price and income on residential electricity consumption. However, as expected, the results vary with data types as well as geographic locations and house stocking. Intuitively, it is expected that consumption decreases with price increase. However, consumption can increase with price increase as well, provided that income increases at the same rate or higher than the price increase. We believe the State of Hawaii, particularly the island of Oahu, presents a unique opportunity to examine the factors affecting residential electricity consumption, especially those of price, income and household size since year round temperatures do not vary much. In subsequent sections, we will examine the effect of each factor on residential electricity consumption and compare it with those of Arizona, California, Florida and Texas. We selected these states for comparison because these States are largely located in USA Climate Zones I, II, and III.

## 2. Hawaii residential electricity consumption

The State of Hawaii is comprised of several islands. The island of Oahu with a population of over 950,000 makes up 70% of the entire population of the State of Hawaii. 98.6% of the population on Oahu resides in urban areas. The island of Maui and the island of Hawaii (also known as the Big Island) are two other large islands with sizable populations.

The State of Hawaii publishes Hawaii State Data Book annually. The Data Book lists electricity usage as well as the income and other relevant information about the islands. Thus, one can easily deduce the electricity production, residential electricity consumption and its prices from the Hawaii Data Book (DBEDT, 2015).

### 2.1. The Island of Oahu

There are only two seasons on Oahu: Summer and Winter. Winter months are slightly cooler with a few degree Celsius differences. Fig. 1 shows the average maximum and minimum monthly temperatures in Honolulu, Oahu. Due to these mild temperatures, no heating is necessary on Oahu and year round trade winds make it comfortable for most of the islanders. Therefore, variations in cooling days have a minimal, if any effect on the residential annual electricity consumption on Oahu.

It should be noted that all data in this section is extracted from the State of Hawaii Data Book (DBEDT, 2015), except when otherwise stated. Also, income per capita and residential electricity usages for other states' data were obtained from the US DOE.