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CONTENTS– continued on outside back cover

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Energy consumption trends in Hawaii

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ABSTRACT

This study begins with a review of energy consumption by end-use sector in Hawaii. Then, the energy generated from renewable energy sources is analyzed between 1991 and 2006. The results show that while geothermal is a considerable source of renewable energy on the Island of Hawaii (also known as Big Island), fossil fuel is the main energy source in the State of Hawaii. The energy intensity index for the State of Hawaii is then calculated by dividing energy consumption per capita by the income per capita. The calculated energy intensity index reveals that energy consumption is directly controlled by per capita income. The results also indicate that the energy intensity index increases over time despite positive developments in energy efficient technologies. In the second part of the paper, the effect of the tourism industry on energy usage in the State of Hawaii is analyzed. The results show that tourism volume, measured in terms of tourist arrival numbers, does not change the energy consumption directly. However, a change in tourism volume does affect per capita income within a few months to a year. In the last part of the study, the energy efficiency index of Hawaii is compared with consumption averages for the US, California and the most energy efficient country in Europe, Denmark. The comparison shows that Hawaii lags behind California and Denmark in terms of energy efficiency. The comparison also shows that an increase in energy efficiency corresponds to an increase in per capita income across the board, which is in agreement with a recent report published by the American Physical Society.

1. Introduction

With recent spikes in oil prices and rising concern over global warming, energy-sourcing and energy consumption trends are discussed at every level of society. There is a growing consensus among politicians, government institutions and the public to reduce dependency on fossil fuels and decrease carbon output by exploring renewable energy resources, increasing the efficiency of energy conversion and improving energy consumption technologies. To this extent, researchers, entrepreneurs, and manufactures are investing extensively in several renewable energy technologies, including solar photovoltaic, wind power, geothermal energy, biomass, and ethanol.

It is important to point out that there currently appears to be no single "silver bullet" solution that will provide enough renewable energy to meet the world's future energy needs, so a diverse portfolio of sustainable energy generation and energy efficiency technologies must be explored. Also, the extent of energy production from renewable energy sources using current technologies is limited. While a discussion on suitable sources of renewable energy is beyond the scope of this paper, it should be noted that some power sources, especially those from biomass such as biofuels are not sustainable when food, water, energy and climate changes issues are considered in a comprehensive analysis. While such an analysis is beyond the scope of this paper, please refer to Pimentel [1] for an excellent discussion on advantages and limitations of possible renewable energy resources.

This paper proposes that decreasing both the short- and long-term energy usage per capita should be encouraged through effective policy and technological developments for improved energy efficiency. This claim is supported by a recent report from the American Physical Society (APS), which states "energy efficiency is one of America's great hidden energy reserves". To begin to tap such hidden reserves, current trends in a region's energy efficiency must be determined. These trends can be used to develop effective policy and incentive programs to increase energy efficiency. To analyze such trends in Hawaii, this paper first investigates historic energy consumption using the data listed in the State of Hawaii Department of Business, Economic Development and Tourism's (DBEDT) State of Hawaii Data Book. In the investigation, the data of 1991 is used as the baseline since it is followed by annual data up to 2006. Then, we determine the energy efficiency of the state of Hawaii and compare it with those of other states in order to determine the potential for improvements.

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2. Electricity generation in Hawaii

The State of Hawaii consists of eight individual islands, each with an independent electrical grid. Hawaiian Electric Industries (HEI) is the parent company to four electrical utility subsidiaries, which supply electricity to Maui, Molokai, Lanai, the Big Island and Oahu. Combined they serve 95% of the State's 1.2 million residents. Hawaiian Electric Company (HECO) provides electric utility to the Island of Oahu; Hawaii Electric and Lighting Company (HELCO) provides electric utility for the Big Island; Maui Electric Company (MECO) provides electric utility for Maui, Lanai and Molokai. Kauai Island Utility Cooperative is an independent electric utility company that provides electricity to Kauai. There are three electric generating plants producing power in Oahu, which provide roughly 70% of the electricity to the State of Hawaii.

Each island has its own power generating facilities, as there is no inter-island grid. This makes Hawaii especially vulnerable in the event of a short- or long-term emergency, since it cannot turn to neighbors like other mainland states. Thus, it is in the best interest of the electric utility companies in Hawaii to develop several energy sources, maximize efficiency and strive for energy independence.

3. Energy consumption by end-use sector

Fig. 1 shows the energy consumption in Hawaii by the end-use sector from 1960 to 2006. This figure reveals that energy consumption by all end-user sectors increased up until 1990 when the energy consumption by transportation and industrial sectors began to decrease. However, energy usage by transportation sector increased after 1990. The total energy consumption followed, more or less, that of the transportation sector as shown in Fig. 1. A quick comparison of other States' energy usage trends, using the comparison chart provided by the U.S. Department of Energy at http://apps1.eere.energy.gov, reveals that Hawaii's transportation sector energy usage per capita is the lowest in the USA. This is because about 64% of Hawaiians reside in the urban areas and driving distances are relatively short.

Note that Fig. 1 also reveals that energy consumption by the residential sector was higher than that of the commercial sector until 1990 when this trend reversed. However, energy consumption in both residential and commercial sectors remains the lowest among all other sectors.

One can observe from Fig. 1 that energy consumption is well reflected by changes in socio-economic structure as demonstrated by the significant shifts in both areas beginning in 1990. The sugar industry had been a significant sector in the State of Hawaii until 1990. At that point sugar production decreased rapidly, in turn reducing overall energy consumption in the State as shown in the energy usage trend in Fig. 1. It appears that energy use by the sugar industry decreased with transportation decreases over time. Nonetheless, energy usage by the transportation sector remains the largest it's been since 1960 in Hawaii.

4. Electricity production sources in Hawaii

Fig. 2 shows the electricity generation sources in the State of Hawaii since 1989 (State of Hawaii Data Book, 2007). As noted from Fig. 2, oil and coal comprise 90% of the State's electricity generation resources. As Hawaii has no fossil fuel resources both oil and coal have to be imported. The percentage of renewable energy sources more or less remains around 10%. Thus, electricity generation from renewable energy sources does not capitalize on the potential despite very favorable environmental conditions. However, the contribution of renewable energy in electricity generation may increase in the future as extensive photovoltaic panels have been installed since 2007 due to new state and federal government incentive and mandate programs. For example, one of the mandate programs requires installation of solar water heating panels to buildings constructed after 2010. Furthermore, the State of Hawaii also mandated in Hawaii's Renewable Portfolio Standard (RPS) that the electric utility companies must provide 10% of their electricity from renewable sources by 2010. This RPS requirement increases to 15% by 2015 and 30% by 2020. It is interesting to note that the mandated electricity generation from renewable sources in the early 1990s was about the same amount mandated for 2010. Thus, the utility companies can meet the mandated requirements with little effort.

Fig. 3 shows the distribution of energy resources in the Islands and State of Hawaii. Table 1 lists the contribution of each energy source to the total electricity generation. A review of Fig. 3 and Table 1 reveals that the Island of Hawaii currently produces nearly a quarter of its electricity from renewable resources – largely from geothermal. Whereas, less populated islands such as Molokai and Lanai generate all their electricity from petroleum. However, the electricity generation sources can change in the future since a few companies plan to generate electricity from renewable energy sources such as wind and algae in Molokai and other islands.

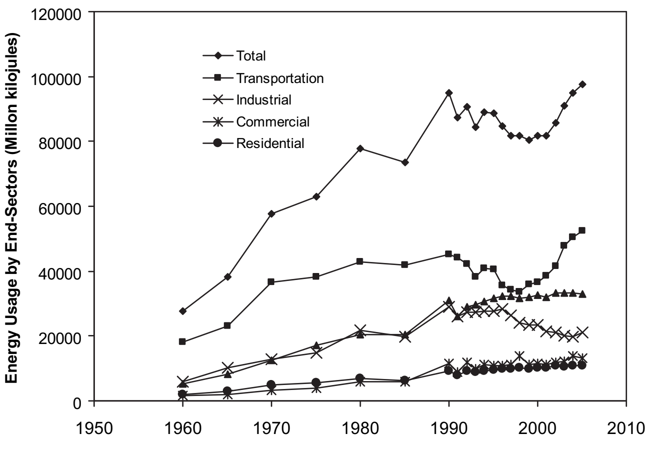

Fig. 1. Energy consumption by end-use sectors in Hawaii.

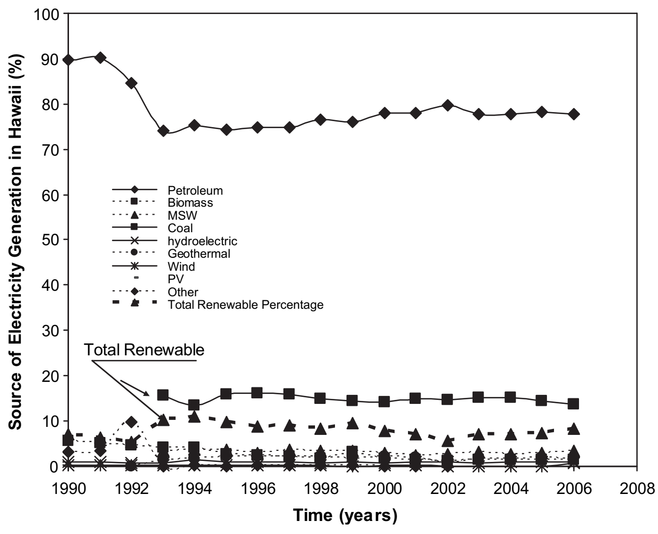

Fig. 2. Sources of energy production in Hawaii.

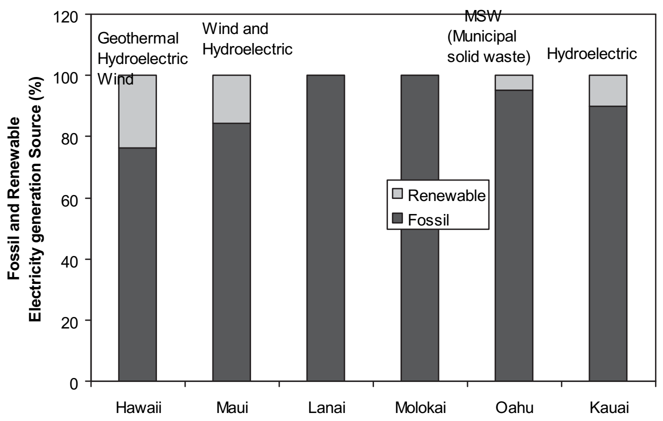

Fig. 3. Sources of electricity production in islands of State of Hawaii.

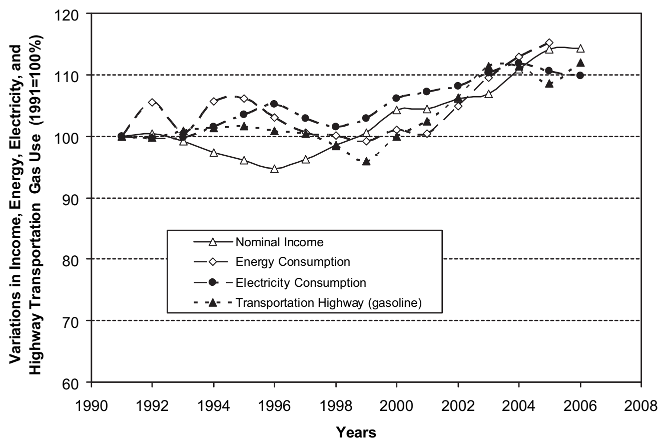

Fig. 4. Variation in energy consumption and income level with time (1991 = 100%).

5. Energy intensity index of Hawaii

To determine the variation of electricity, energy consumption and income per capita in the State of Hawaii, we normalized the values of these variables with respect to those of 1991. The values of these variables in 1991 are set to 100% in order to establish a baseline. Then, variations in these variables in subsequent years are plotted with respect to 1991.

Fig. 4 shows variations of electricity, energy consumption and nominal income per capita with time in the State of Hawaii. As noted in Fig. 4, energy, electricity and highway gas use increased slightly despite the decrease in gross domestic product (GDP) until the late 1990s. Then, electricity and highway gas usage increased with the increase in GDP indicating that an increase in GDP causes an increase in highway gas and electrical use. We deliberately excluded energy usage in other transportation sectors to determine if there are changes in highway gas usage trends due to the introduction of new gas efficient cars and hybrid vehicles.

Fig. 4 shows Hawaii's energy, highway gas, and electricity usages, with nominal income that is normalized with respect to 1991 values. Note that Fig. 4 shows these normalized variables increase almost linearly after 1998. This trend implies that there is a possible correlation between income level and energy, electricity and highway gas usage. Thus, it is necessary to determine how energy, highway gas usage and electricity usage depends on GDP.

Energy intensity, defined as energy use per capita divided by GDP per capita, or energy consumption per GDP [2], is another measure used to compare the energy consumption and efficiency trends [3]. Energy intensity is normalized with respect to a baseline year. Energy intensity shows how efficiently energy is used to produce a unit of income. Thus, in principle, the lower the energy intensity indicates the more efficient the economy. This is because the energy intensity index also shows the quantity of work gained without compromising comfort and production. The work gain is mostly realized by using energy efficient technologies. Similar to energy intensity, we define a highway gas intensity index and an electrical sale intensity index by dividing these variables per capita of GDP. Then, we normalize the electricity sale intensity index and highway gas use index with respect to those of 1991 (i.e., 1991 = 100). The calculated intensity index values are presented in Fig. 5.

From Fig. 5, Hawaii's energy intensity, electricity sale intensity and highway gas intensities do not decrease over time despite availability of energy efficient technologies in the market. Further, Fig. 5 suggests that energy, electricity sale and highway gas intensity fluctuate over a period of about 10 years. Latzko [4] also reports that Hawaii's economy moves at a 5 year cycle.

In short, Figs. 4 and 5 suggest GDP directly controls the energy usage in Hawaii, especially after 1998. In other words, a decrease in energy consumption is not because of adapting energy efficient technologies or energy policies; rather it is because of a decrease in GDP. This is important especially when one considers that utility companies in the State of Hawaii have paid through their demand side management programs more than $74 million in rebates since the late 1990s to help commercial and residential customers offset the initial cost of investing in energy efficient technologies [5]. However, it appears that electricity utility companies' demand side management programs have limited effect on reducing the electricity demand. Thus, both state and utility officers need to revisit their energy programs to increase the State's energy consumption performance. This is very important since energy use reduction has been emphasized by energy policy makers and energy suppliers including those of the DBEDT and those of electric utility companies. Further, it should be noted that Figs. 4 and 5 indicate that energy conservation is not detectable. Thus, a serious effort must be placed in incentive programs in energy conservation, which is stated by APS [6] as "America's hidden energy reserve".

Table 1
Contributions to electricity generation in Hawaii in 2006.

	Total	Petroleum	Coal	Biomass	MSW	Hydroelectric	Wind	Geothermal	Photovoltaic	Fossil	Renewable	Fossil (%)	Renew (%)
	Million kWh												
State	11,704	9109	1613	170	388	128	82	212	2	10,722	982	91.6	8.4
Hawaii	1255	959				58	25	212	1	959	296	76.4	23.6
Maui	1386	1126	42	134		27	57			1168	218	84.3	15.7
Lanai	30	30								30	0	100.0	0.0
Molokai	39	39								39	0	100.0	0.0
Oahu	8495	6507	1571	28	388				1	8078	417	95.1	4.9
Kauai	499	448		8		43				448	51	89.8	10.2

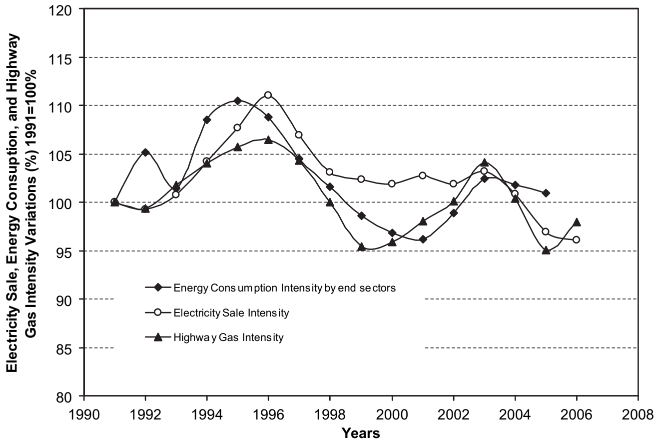

Fig. 5. Variations in energy consumption in energy usage in Hawaii with time (1991 = 100%).

6. The significance of the tourism industry on energy consumption

The tourism industry, with about 7 million visitors annually, makes about one-third of Hawaii's gross state income. Tabatchnaia-Tamirisa et al. [7] reported that the tourism industry, directly or indirectly, comprises 40% of the total energy demand in Hawaii. They further reported that energy literally sustains Hawaii's tourism economy. Later, Latzko [4] analyzed the dependency of Hawaii on the tourism industry using employment numbers of Federal Government, tourism and agriculture industries, and tourist arrival numbers between 1969 and 2001. Based on research findings, Latzko [4] concluded, "fluctuations in the Hawaiian economy are strongly correlated with fluctuations in the number of tourists". Further, he found that the tourism industry has its most immediate impact on gross state product, followed in a few months by personal income. Latzko [4] also noted that employment is affected after a lag of about 1 year. Thus, it is necessary to investigate the effect of tourism arrival trends on energy, electricity and highway gas uses. To do so, we normalized tourist arrivals and GDP per capita with respect to 1991 as given by the State of Hawaii Data Book (2007). To differentiate the normalized tourist arrival numbers from the normalized tourism arrival number by GDP, we call the latter the tourist index. The variation of tourist index and GDP with respect to values in 1991 are plotted along with energy consumption, electricity sale and highway gas intensity indexes (Fig. 6). We also plot variations of tourist arrival numbers with

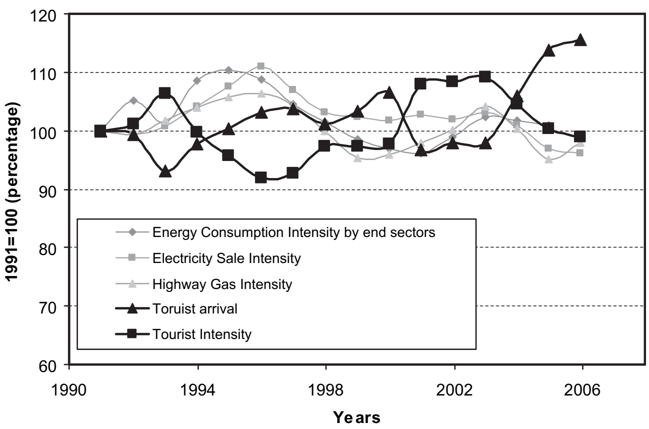

Fig. 6. Variations in comparison of tourist arrival index with energy usage intensity.

nominal income (Fig. 7). Both Figs. 6 and 7 reveal the following information:

(i) there is no significant correlation between tourism arrival numbers and gas, energy and electricity sale intensities;
(ii) GDP per capita correlates with tourist arrival numbers (tourist volume) with a lag of a few months to a year.

Therefore, electricity use is not significantly directly related to tourist arrival numbers. This is because tourism industry facilities such as neon lights or air conditions run almost at full capacity regardless of the tourist numbers. For example, air conditioning is run in hotel rooms to prevent mold formation whether they are occupied or not. Thus, use of electricity per capita does not show variations with tourist arrival numbers.

As shown in Fig. 6, highway gas intensity does not vary with the number of tourist arrivals. This is partially due to the fact that 70% of tourists arrive and stay on Oahu, with limited driving activity. This poor correlation between highway gas use and tourist arrival numbers is better understood when it is considered that more than 40% of tourists arriving on Oahu stay in Waikiki. This comprises 8% of Hawaii's GDP (DBEDT, 2003). Fig. 6 shows that Hawaii's economy is indeed largely driven by the tourism industry. Further, the phase lag between tourist index and energy, electricity, and highway gas use intensities is in strong agreement with the findings of Latzko [4]. Note that even though Latzko [4] and this study use different variables to evaluate the dependency of Hawaii on the tourism industry, both studies reach the same conclusions.

7. Correlation between energy use and economic growth

As noted in the report published by the APS, some critics argue that reducing per capita energy use through improved efficiency could depress economic growth [8]. The APS report argued that California's experience suggests otherwise. They support their claim with data from California's program to improve electric use efficiency, which was established in 1975. To shed light on this dilemma, we compare the Hawaii GDP and energy usage per capita with those of the US average, California and Denmark. We note that reported energy data varies with the agencies such as those reported by IEA and EIA. We used the data presented at http://www.dst.dk/library for Denmark.

We chose Denmark for several reasons. Denmark: (i) is a world leader in the use of renewable energy (especially developing wind energy technology); (ii) has one of the highest GDP's in the European Union (EU); (iii) has the lowest energy intensity in the EU; (iv) has an electricity usage per capita similar to those of California and Hawaii (6000–8000 kWh); and (v) has an active energy policy to

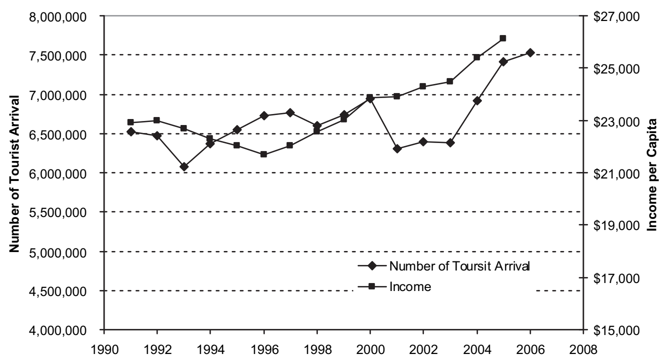

Fig. 7. Variation of GDP of Hawaii with tourist arrival volume.

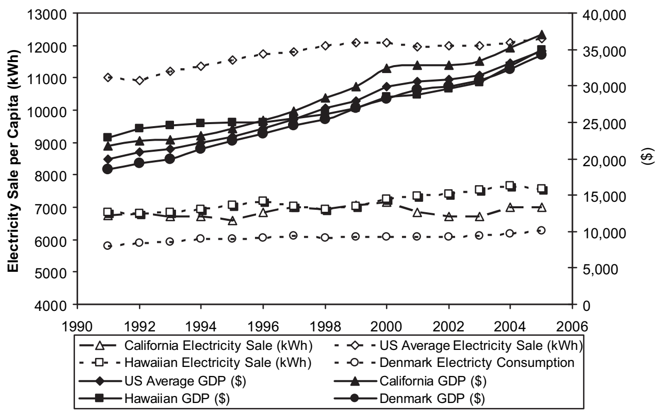

Fig. 8. Comparison of energy use and income per capita for Hawaii, US average, California and Denmark.

increase energy efficiency while maintaining high economic growth.

Fig. 8 compares GDPs and energy usage of Hawaii with those of the US average, California and Denmark. Fig. 8, reveals the following:

(i) In the early 1990s, the electricity use per capita in California and Hawaii were almost identical while California's GDP was less than that of Hawaii. In the mid 1990s, California's electricity use per capita decreased while its GDP increased and surpassed that of Hawaii. The GDP and electricity use trends remain more or less the same for both States.

(ii) Hawaii's GDP was higher than that of the US average until the mid 1990s; then it started to lag behind the US average while its electricity use increased.

(iii) Denmark's GDP increased by 85% while energy usage increased 8% for the same period (1991–2005). Conversely, Hawaii's GDP increased only 52% while energy usage increased 6%. Note that the energy usage of Denmark in 2005 is 17% less than that of Hawaii; yet, they have practically the same GDP. In other words, Denmark produced more than Hawaii for every kWh of consumed electricity. This comparison clearly shows that Denmark is more energy efficient than Hawaii.

In Fig. 8, both electricity use and GDP variation have different slopes thus, it is hard to visualize these variables in terms of efficiency. Fig. 9 shows the electricity intensity index of the US, Denmark, California and Hawaii with year 1991 represented by 100% in the graph. Note that Denmark consistently has the lowest

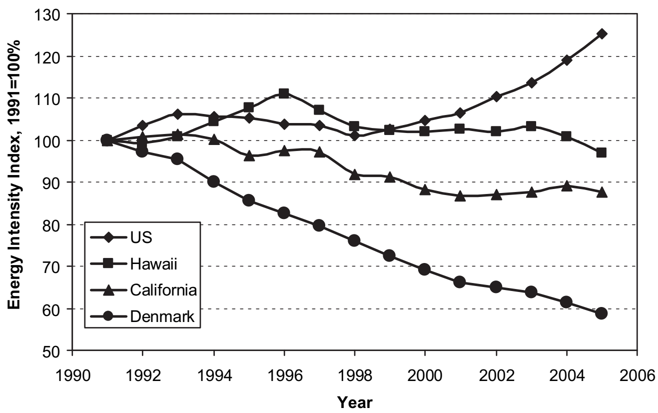

Fig. 9. Comparison of electric intensities of Hawaii, US average, California and Denmark.

electricity intensity over time, which reflects its constantly increasing GDP. On the other hand, Hawaii's electricity intensity increases due to inefficient electricity use. More importantly, Fig. 9 also indicates that the energy usage per capita does not decrease the economic growth, which reflects the findings of the APS report. Contrary to a common misconception [8–11], experiences of both Denmark and California show that an increase in energy efficiency stimulates economic growth if GDP is an indicator of economic growth. Thus, energy policy makers, engineers, scientist and entrepreneurs should place equal, if not more, emphasis on decreasing energy use by adapting policies and technologies to improve energy efficiency.

As stated above, Figs. 8 and 9 show that no change in the energy conservation per capita base is noticeable in the State of Hawaii. Thus, there is a need to develop new programs to encourage energy conservation and energy efficient technologies in the State of Hawaii.

8. Conclusions

Based on the data and discussion presented above the following can be concluded:

1. Although Hawaii has potential to provide much needed renewable energy sources such as geothermal, wind, ocean wave, it has not totally utilized these resources meaningfully.
2. Most of the energy in Hawaii is used by the transportation sector; however, its use is lower than those of the US average due to relatively short driving distances. Increases in gas mileage in the transportation industry have not shown its effect since energy usage in transportation industry increases per capita. It appears that energy usage per capita is controlled by income per capita more than anything else.
3. The results also reveal that per capita income is controlled by the volume of tourist arrival with a phase lag of a few months to a year.
4. Comparison of electricity intensities, indicator of electricity use efficiency of Hawaii, US average, California and Denmark shows that Hawaii is not as efficient as Denmark and California. Hawaii's energy intensities remain more or less the same between 1991 and 2005.
5. To remain sustainable and competent, Hawaii needs to develop policies to encourage energy conservation and the use of energy efficient technologies, perhaps emulating the policies of California and Denmark.

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