Status of Renewable Primary Energy and Renewable Electricity in Hawaii

July 2018
Department of Business, Economic Development & Tourism
Research and Economic Analysis Division

This report is prepared by Dr. Binsheng Li, Economist, under the direction of Dr. Eugene Tian, Division Administrator. Dr. Joseph Roos, Economic Research Program Manager, reviewed and provided valuable inputs for this report.

TABLE OF CONTENTS

LIST OF TABLES

SECTION 2 TABLES

SECTION 3 TABLES

SECTION 4 TABLES

SECTION 5 TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Energy can be classified into primary energy and secondary energy based on its sources. A primary source of energy is one that occurs naturally. Fossil fuels (coal, oil and gas), biofuels, wind, waves, solar radiation and nuclear fuels are all primary sources of energy. A secondary energy source is one that is made using a primary source. Electricity is secondary source and can be generated by primary sources.

This report focuses on the renewable portion of the energy sources. On the primary energy side, this report provides statistics and analysis in detail on renewable sources and the major sectors using these renewable sources from the consumption context. All the primary energy consumptions are measured in the British thermal unit (BTU). On the secondary energy side, this report provides information on the detailed electricity generated by renewable sources of energy. The electricity generation is measured by gigawatt hours (GWH).

Renewable Primary Energy

Hawaii's renewable energy development started late compared with other states in the nation. In 1960, primary energy from renewable sources accounted for only 0.3% of the total while the U.S. average was 6.5% that year. With the rapid development of biomass in the early 1980s, the percentage of Hawaii's renewable primary energy became 9.3% in 1989, higher than the U.S. average at 8.7% for that year. By 2015, the latest year data are available, Hawaii's renewable primary energy accounted for 10.2% of the total primary energy consumption, higher than that of the U.S. at 9.5% for the same year (Tables 2.2 and 2.4).

Renewable primary energy mainly includes: biomass which includes wood & waste (W&W) and ethanol, geothermal, hydro, wind, and solar. Among the renewable energy sources consumed, Hawaii had relatively larger shares in solar and geothermal (29.0% and 7.5%, respectively for Hawaii; 4.6% and 2.3%, respectively for U.S. in 2015) while U.S. had heavier use of biomass and hydro (48.8% and 25.1%, respectively for U.S.; 39.8% and 3.9%, respectively for Hawaii in 2015). The use of wind energy was about the same between Hawaii and the nation (19.8% for Hawaii and 19.2% for U.S. in 2015) (Tables 2.3 and 2.5).

Following is a brief history of renewable primary energy consumptions in Hawaii:

Biomass: W&W was introduced in Mid 1960s and increased rapidly during 1980s and reached peak level in 1989. From 1989 to 2002, W&W consumption decreased substantially, causing the share of renewable primary energy decreased substantially. From 2002 to 2015, W&W consumption stabilized at an average of 8,000 billion BTU (BBTUs) a year (Table 3.1).

Before 2005, all biomass consumed in Hawaii was W&W. Fuel ethanol consumption started in 2005. From 2005 to 2015, fuel ethanol consumption increased from 1,183 BBTUs in 2005 to 3,939 BBTUs in 2015, a 233% increase (Table 3.1).

Geothermal: Hawaii started using geothermal in 1985, but not until 1993 when the geothermal usage became stable. From 1993 to 2015, geothermal consumption fluctuated between 1,600 to 2,700 BBTUs. In 2015, geothermal consumption was 2,154 BBTUs. Geothermal was almost entirely used for electricity generation (Table 3.4).

Hydro: Hawaii's hydro energy was the first renewable energy source developed in the 1960s. Consumption of hydro energy was fluctuating around 1,000 BBTUs over the half century. Hydro energy was used in the electricity sector and the industrial sector (Table 3.5).

Solar: Hawaii's solar energy (including customer sited solar – photovoltaic and solar water heating) consumption began in 1989. Before 2005, solar energy was mainly consumed in the residential sector. Commercial sector accelerated solar energy development since 2005. Between 2005 and 2015, solar energy used by commercial sector increased 162 times, from 14 BBTUs to 2,267 BBTUS. Since 2009, solar energy started to play a role in utility scale electricity generation. By 2015, total solar energy consumption reached 8,351 BBTUs, represented an increase of 920% from 1989 (Table 3.6).

Wind: Hawaii started to use wind energy in 1989, and this energy source grew the fastest among all the renewable sources. From 1989 to 2015, wind energy consumption increased from 344 BBTUs to 5,710 BBTUs, representing a 1,560% increase. Wind energy was entirely used in electricity generation (Table 2.1).

Major Energy Users

The U.S. Energy Information Administration (EIA) defined the users of primary energy into five sectors: (1) **Transportation sector:** Consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. (2) **Industrial sector:** Consists of all facilities and equipment used for producing, processing, or assembling goods. (3) **Commercial/Institutional sector:** Consists of service-providing facilities and equipment of businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. (4) **Residential sector:** Consists of living quarters for private households, and (5) **Electric Power sector**: Consists of electricity generation facilities. The first four are end use sectors and the electricity sector generates and provide secondary energy sources.

In this EIA definition, the consumptions of customer sited solar by industrial, commercial, and residential sectors, mainly in the form of photovoltaic electricity generation and solar water heating, are included in these sectors rather than in the electricity sector. The consumption of the primary energy by the electricity sector in section 4 refers only those energy sources used by the utility scale power producers.

In terms of primary energy, the largest user of primary energy in Hawaii was the transportation sector which consisted of vehicles transporting people and goods, consumed over half (51.4%) of the total state primary energy in 2015, followed by the

electricity sector at 32.4%, industrial sector at 10.1%, commercial sector at 3.8%. Residential sector consumed 2.3% of the primary energy (Table 4.1).

After allocating electricity into the other end use sectors, transportation was still the highest energy user at 51.4%, industrial use became the second largest at 22.7%, followed by commercial sector at 14.6%, and residential sector at 11.3% in 2015 (Table 4.3).

In terms of renewable energy sources, electricity sector used 34.0% of the total renewable sources developed, followed by residential sector at 20.4%, commercial sector at 19.5%, industrial sector at 13.2%, and transportation sector used 12.9% of the total renewable energy sources in 2015 (Table 4.4).

Renewable Electricity

The calculation of the renewable electricity is complicated for the following reasons:

1. EIA data classified customer sited PV in its end use sectors such as industrial, commercial, residential, and electricity sectors with residential sector used the most customer sited PV. In other words, customer sited PV was not included in the electricity sector.
2. The renewable energy consumed by the electricity sector is calculated at the primary energy level, measured in BTUs (the 10.7% number for 2015).
3. The renewable electricity generated by the electricity sector is calculated at the secondary energy level, measured in GWHs (the 16.9% number for 2015 and 17.7% for 2016).
4. The difference between the share of renewable for the electricity sector at the primary energy level and the secondary energy level is due to the difference in the conversion efficiencies between fossil fuel generated electricity and renewable energy generated electricity. For example, to generate one kWh of electricity, 9,725 BTUs of fossil fuel is required while only 5,736 BTUs of renewable energy is required to generate one kWh of electricity.
5. The renewable electricity can further be calculated by including electricity generated by customer sited PV (the 23.3% and 26.6% numbers for 2016)

This report attempts to estimate the renewable energy and electricity of the electricity sector under different definitions.
According to the data from EIA, the consumption of the primary renewable energy, measured by BTUs, by the electricity sector accounted for 10.7% of the total primary energy sources consumed by the electricity sector.

Measuring at the secondary energy level, the share of electricity generated using renewable sources (renewable electricity), measured by GWH, by the electricity sector, excluding the electricity generated from customer sited solar systems, decreased from 9.8% in 1990 to 5.2% in 2002. From 2002 to 2016, the share of renewable electricity increased from 5.2% to 17.7%. The decrease from 1990 to 2002 was mainly due to

decreased W&W generated electricity; and the increase from 2002 to 2016 was mainly due to increased wind and solar generated electricity (Table 5.1).

The renewable electricity data from EIA included only the electricity generated by the electric power industry. Electricity generated by customer sited solar systems was not included. However, the Renewable Portfolio Standard (RPS) Status Report submitted to the State Public Utilities Commission (PUC) by the utility companies included data on the customer-sited solar electricity generation. According to the RPS report, in 2016, the customer-sited solar systems generated about 827 GWH of electricity and the report revealed that renewable electricity accounted for 26.6% of total electricity sold in 2016 (Table 5.3).

Based on the RPS data, from 2005 to 2016, the share of biomass generated electricity decreased from 56% to 19%; the share of biofuels increased from 0% to 2%; the share of geothermal decreased from 31% to 11%; the share of hydro decreased from 12% to 4%; the share of wind increased from 1% to 27%, the share of solar (excluding customer-sited solar) increased from 0% to 5%; and the share of customer-sited solar increased from 0% to 34% (Table 5.4).

The renewable electricity ratio (26.6% in 2016) in the RPS was calculated by dividing total electricity sold by utilities into electricity generated using renewable sources by both the electric power industry and customer sited solar systems:

$$\%\ of\ renewable\ electricity = \frac{Net\ electricity\ generation\ from\ renewable\ sources + \text{electricity generated by customer sited PV}}{Total\ electricity\ sold\ by\ utilities} \times 100$$

This report recalculated the renewable electricity ratio (the Alternative method) by employing the formula below:

$$\%\ of\ renewable\ electricity = \frac{Net\ electricity\ generated\ from\ renewable\ sources + electricity\ generated\ by\ \text{customer sited PV}}{Net\ generation\ of\ the\ electricty\ industry\ * + electricity\ generated\ by\ \text{customer sited}\ PV} \times 100$$

*The electricity industry includes electric utilities, independent power producers (IPP), and combined heat and power producers (CHP).

Based on the Alternative methodology and the RPS data, the share of renewable electricity in 2016 was 23.3%, lower than the share from the RPS report (26.6%), but higher than the share calculated using the EIA data (17.7%).

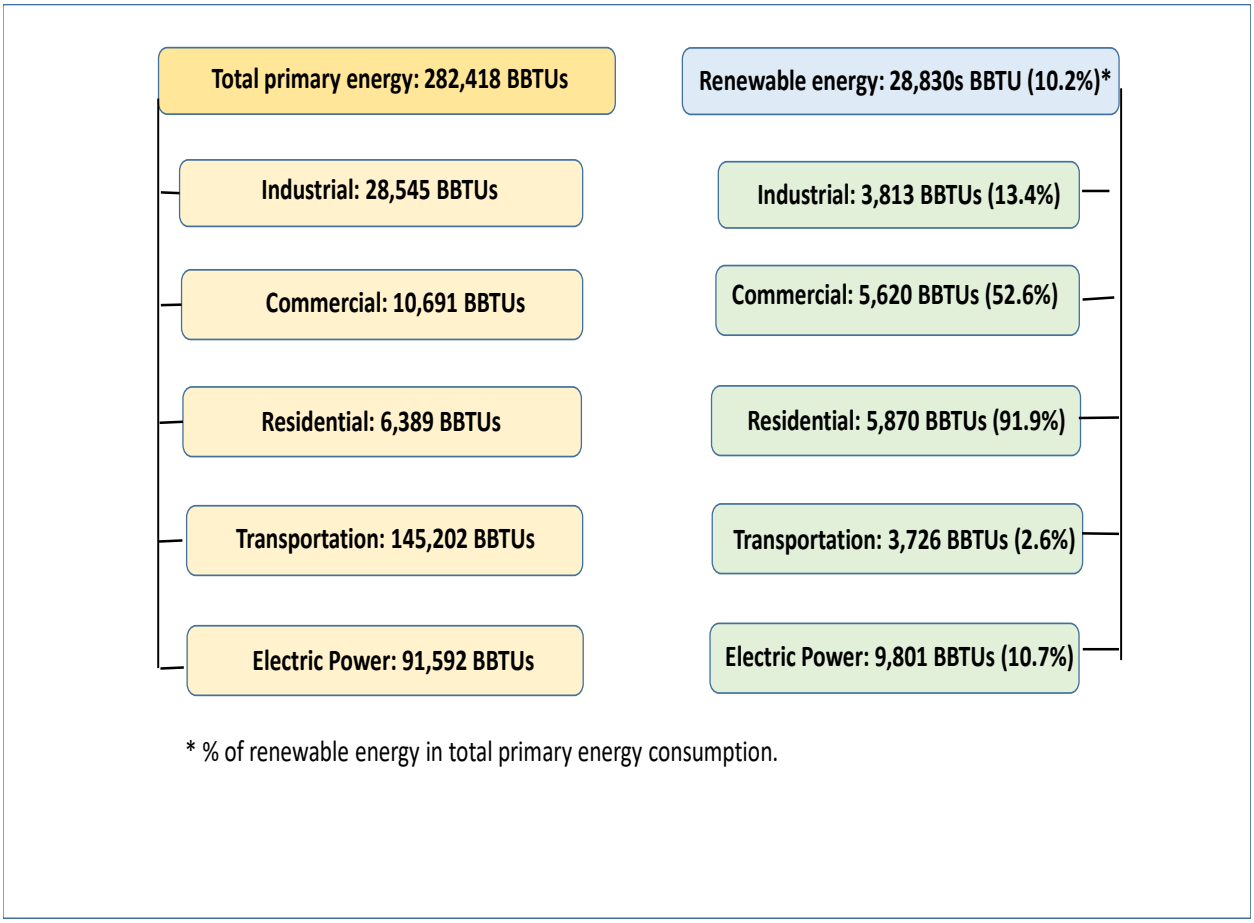
1. INTRODUCTION

Act 097 SLH 2015 increased the 2020 Renewable Portfolio Standard (RPS) target to 30%, maintained the 2030 RPS target at 40%, added a 2040 RPS target to 70%, and added a 2045 RPS target of 100%. Hawaii's clean energy goals are the most aggressive in the nation. Although the RPS target is for electricity only, it is also useful to know the renewable energy development status of total primary energy. This study examines the historical performance of Hawaii's renewable primary energy and renewable electricity development by source of energy and by usage sector.

Energy can be classified into primary energy and secondary energy based on its sources. A primary source of energy is one that occurs naturally. Fossil fuels (coal, oil and gas), biofuels, wind, waves, solar radiation and nuclear fuels are all primary sources of energy. A secondary energy source is one that is made using a primary source. Electricity is secondary source and can be generated by primary sources.

This report focuses on the renewable portion of the energy sources. On the primary energy side, this report provides statistics and analysis on detailed renewable sources and the major sectors using these renewable sources. All the primary energy consumptions are measured in the British thermal unit (BTU). Figure 1 below shows the primary energy consumption by sector in 2015 based on data from the U.S. Energy Information Administration (EIA). In 2015, 10.7% of the primary energy consumed in the electricity sector was renewable energy.

Figure 1.1 Hawaii Energy and Renewable Energy Consumption by Sector (2015)

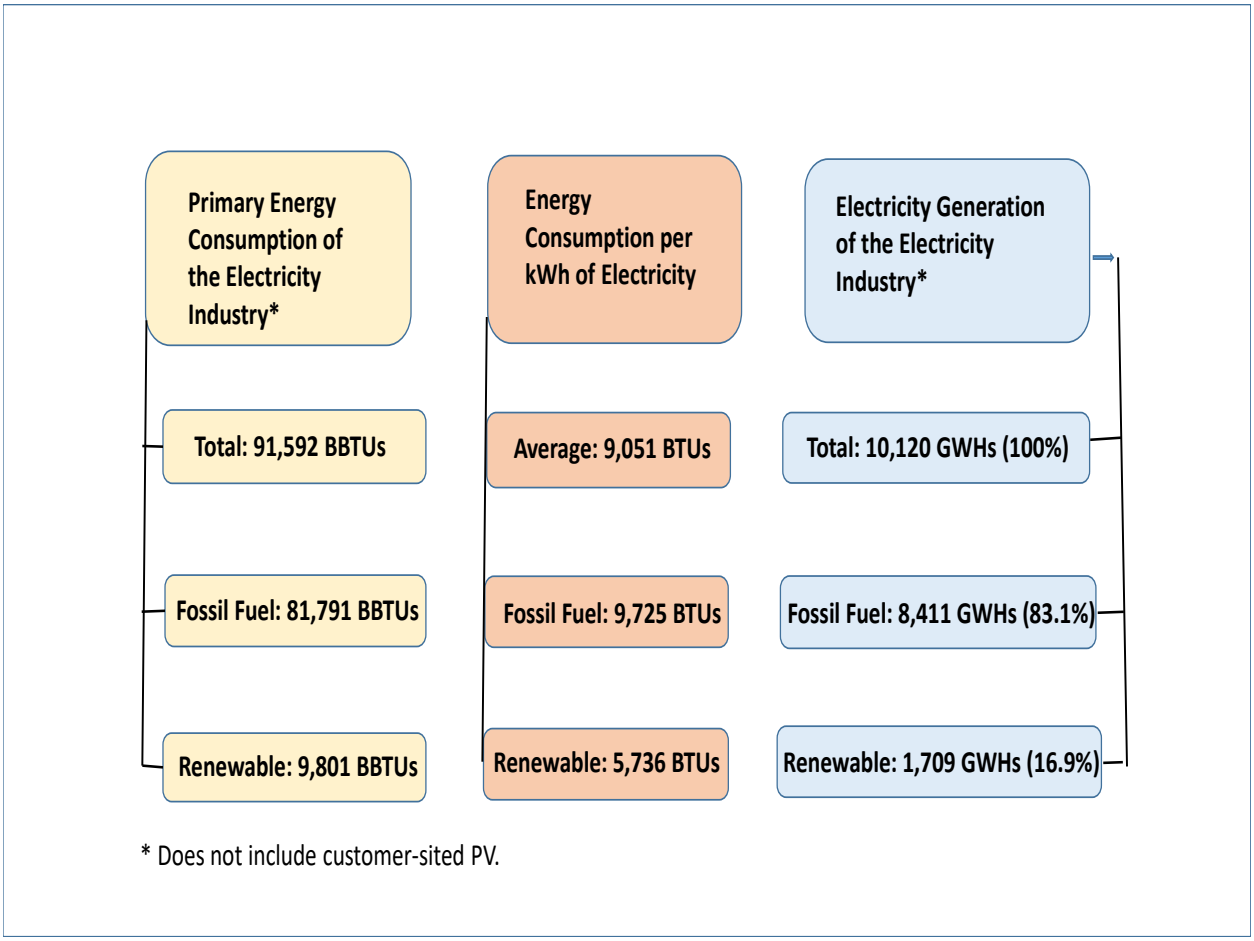


On the secondary energy side, this report provides information on the electricity generated by renewable energy sources in the electricity sector. In 2015, the electricity sector generated 10,120 GWH electricity, about 1,709 GWH or 16.9% was generated by renewable energy sources.

The difference between the share of renewable for the electricity sector at the primary energy level and the secondary energy level is due to the difference in the conversion efficiencies between fossil fuel generated electricity and renewable energy generated electricity. For example, to generate one kWh of electricity, 9,725 BTUs of fossil fuel is required while only 5,736 BTUs of renewable energy is required to generate one kWh of electricity.

Figure 2 presents the energy consumption by the electricity sector at the primary energy level (measured in BTUs) and at the secondary level (measured by GWHs).

Figure 1.2 Hawaii Renewable Electricity Generation (2015)



There are three major data sources for this report. The first one is the U.S. Energy Information Administration (EIA). The EIA data include two parts, data from the State Energy Data System (SEDS) and data from Detailed State Data in the Electricity (DSDE) section. The most recent SEDS data include energy consumption from 1960 to 2015 by sources of energy. The most recent DSDE data include net electricity generation by source and total retail sales of electricity from 1990 to 2016. Other sources of data include the utility Renewable Portfolio Standard (RPS) Status Report and the utility Monthly Financial Report (MFR). The RPS data include total electricity sold by the utilities and net generation of renewable electricity by source, including electricity generated by customer-sited PV systems from 2005 to 2016.

2. RENEWABLE ENERGY CONSUMPTION IN HAWAII AND THE U.S.

As shown in Table 2.1, before 1980, renewable energy consumed in Hawaii only include a small amount of hydro and biomass. Total renewable energy consumption accounted for less than 1% of Hawaii's total primary energy consumption.

Table 2.1 Hawaii's Renewable Energy Consumption by Source

	Energy Consumption In Billion BTUs						
	Primary	Total	Renewable Energy				
Year	Energy	Renewable	Biomass	Geothermal	Hydro	Solar*	Wind
1960	94,855	292	-	-	292	-	-
1965	130,589	1,265	172	-	1,093	-	-
1970	196,979	1,559	429	-	1,131	-	-
1975	214,429	1,498	569	-	929	-	-
1980	262,456	12,808	11,910	-	898	-	-
1985	248,555	15,307	14,217	197	893	-	-
1986	245,329	17,315	16,314	184	817	-	-
1987	249,461	18,834	17,846	133	855	-	-
1988	289,692	20,427	19,426	168	834	-	-
1989	309,767	28,875	26,984	147	581	819	344
1990	321,421	27,937	25,924	-	827	885	300
1991	295,155	27,516	25,446	-	741	957	372
1992	306,042	26,800	24,901	23	632	1,010	235
1993	282,878	27,829	24,388	1,570	580	1,065	226
1994	299,349	25,404	20,724	1,912	1,438	1,120	210
1995	297,037	24,608	19,803	2,419	1,009	1,168	210
1996	283,262	24,088	19,066	2,502	1,076	1,211	233
1997	273,576	22,502	17,433	2,506	1,178	1,222	164
1998	273,516	21,657	16,548	2,418	1,237	1,257	197
1999	269,448	21,767	16,981	2,162	1,175	1,280	169
2000	273,430	20,386	15,194	2,681	1,055	1,282	173
2001	270,245	12,389	7,947	2,143	1,041	1,236	22
2002	284,802	10,452	7,480	748	967	1,240	16
2003	300,977	13,310	9,305	1,813	916	1,259	16
2004	314,760	13,769	9,336	2,144	941	1,273	75
2005	324,741	14,119	9,565	2,224	962	1,301	66
2006	327,187	15,350	9,875	2,114	1,191	1,380	790
2007	337,743	16,755	9,693	2,280	913	1,516	2,354
2008	276,646	19,097	11,795	2,316	831	1,790	2,365
2009	276,035	19,440	12,225	1,643	1,099	2,019	2,454
2010	276,948	17,937	10,448	1,964	687	2,291	2,547
2011	285,270	19,778	10,550	2,183	905	2,828	3,311
2012	277,794	21,058	9,604	2,491	1,090	4,273	3,599
2013	278,404	25,451	11,179	2,630	747	6,093	4,802
2014	279,001	27,362	11,008	2,422	895	7,534	5,503
2015	282,418	28,830	11,485	2,154	1,129	8,351	5,710

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

Significant W&W was introduced in 1980 and the consumption of W&W increased from 1980 to 1989. From 1989 to 2002, W&W consumption decreased substantially, causing the share of renewable energy decreased substantially. From 2002 to 2015, W&W consumption stabilized, and increased consumption of solar, wind, and fuel ethanol caused the share of renewable energy increased.

Table 2.2 Renewable Energy's Share of Total Primary Energy in Hawaii

	Share of Total Primary Energy Consumption (%)					
	Total	Renewable Energy				
Year	Renewable	Biomass	Geothermal	Hydro	Solar*	Wind
1960	0.3	0.0	0.0	0.3	0.0	0.0
1965	1.0	0.1	0.0	0.8	0.0	0.0
1970	0.8	0.2	0.0	0.6	0.0	0.0
1975	0.7	0.3	0.0	0.4	0.0	0.0
1980	4.9	4.5	0.0	0.3	0.0	0.0
1985	6.2	5.7	0.1	0.4	0.0	0.0
1986	7.1	6.6	0.1	0.3	0.0	0.0
1987	7.5	7.2	0.1	0.3	0.0	0.0
1988	7.1	6.7	0.1	0.3	0.0	0.0
1989	9.3	8.7	0.0	0.2	0.3	0.1
1990	8.7	8.1	0.0	0.3	0.3	0.1
1991	9.3	8.6	0.0	0.3	0.3	0.1
1992	8.8	8.1	0.0	0.2	0.3	0.1
1993	9.8	8.6	0.6	0.2	0.4	0.1
1994	8.5	6.9	0.6	0.5	0.4	0.1
1995	8.3	6.7	0.8	0.3	0.4	0.1
1996	8.5	6.7	0.9	0.4	0.4	0.1
1997	8.2	6.4	0.9	0.4	0.4	0.1
1998	7.9	6.1	0.9	0.5	0.5	0.1
1999	8.1	6.3	0.8	0.4	0.5	0.1
2000	7.5	5.6	1.0	0.4	0.5	0.1
2001	4.6	2.9	0.8	0.4	0.5	0.0
2002	3.7	2.6	0.3	0.3	0.4	0.0
2003	4.4	3.1	0.6	0.3	0.4	0.0
2004	4.4	3.0	0.7	0.3	0.4	0.0
2005	4.3	2.9	0.7	0.3	0.4	0.0
2006	4.7	3.0	0.6	0.4	0.4	0.2
2007	5.0	2.9	0.7	0.3	0.4	0.7
2008	6.9	4.3	0.8	0.3	0.6	0.9
2009	7.0	4.4	0.6	0.4	0.7	0.9
2010	6.5	3.8	0.7	0.2	0.8	0.9
2011	6.9	3.7	0.8	0.3	1.0	1.2
2012	7.6	3.5	0.9	0.4	1.5	1.3
2013	9.1	4.0	0.9	0.3	2.2	1.7
2014	9.8	3.9	0.9	0.3	2.7	2.0
2015	10.2	4.1	0.8	0.4	3.0	2.0

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

As shown in Table 2.2, the renewable energy share of total primary energy consumption increased from 4.9% in 1980 to 9.3% in 1989, decreased to 3.7% in 2002, and then increased to 10.2% in 2015. As shown in Table 2.3, from 1989 to 2015, the biomass' share of total renewable energy consumption decreased from 93.5% to 39.8%; the share of solar increased from 2.8% to 29.0%; the share of wind increased from 1.2% to 19.8%; the share of geothermal increased from 0.5% to 7.5%; and the share of hydro increased from 2.0% to 3.9%.

Table 2.3 Hawaii's Share of Renewable Energy by Source

	Share of Renewable Energy Consumption (%)					
	Total	Renewable Energy				
Year	Renewable	Biomass	Geothermal	Hydro	Solar*	Wind
1960	100.0	0.0	0.0	100.0	0.0	0.0
1965	100.0	13.6	0.0	86.4	0.0	0.0
1970	100.0	27.5	0.0	72.5	0.0	0.0
1975	100.0	38.0	0.0	62.0	0.0	0.0
1980	100.0	93.0	0.0	7.0	0.0	0.0
1985	100.0	92.9	1.3	5.8	0.0	0.0
1986	100.0	94.2	1.1	4.7	0.0	0.0
1987	100.0	94.8	0.7	4.5	0.0	0.0
1988	100.0	95.1	0.8	4.1	0.0	0.0
1989	100.0	93.5	0.5	2.0	2.8	1.2
1990	100.0	92.8	0.0	3.0	3.2	1.1
1991	100.0	92.5	0.0	2.7	3.5	1.4
1992	100.0	92.9	0.1	2.4	3.8	0.9
1993	100.0	87.6	5.6	2.1	3.8	0.8
1994	100.0	81.6	7.5	5.7	4.4	0.8
1995	100.0	80.5	9.8	4.1	4.7	0.9
1996	100.0	79.2	10.4	4.5	5.0	1.0
1997	100.0	77.5	11.1	5.2	5.4	0.7
1998	100.0	76.4	11.2	5.7	5.8	0.9
1999	100.0	78.0	9.9	5.4	5.9	0.8
2000	100.0	74.5	13.2	5.2	6.3	0.8
2001	100.0	64.1	17.3	8.4	10.0	0.2
2002	100.0	71.6	7.2	9.3	11.9	0.2
2003	100.0	69.9	13.6	6.9	9.5	0.1
2004	100.0	67.8	15.6	6.8	9.2	0.5
2005	100.0	67.7	15.8	6.8	9.2	0.5
2006	100.0	64.3	13.8	7.8	9.0	5.1
2007	100.0	57.9	13.6	5.4	9.0	14.0
2008	100.0	61.8	12.1	4.4	9.4	12.4
2009	100.0	62.9	8.5	5.7	10.4	12.6
2010	100.0	58.2	10.9	3.8	12.8	14.2
2011	100.0	53.3	11.0	4.6	14.3	16.7
2012	100.0	45.6	11.8	5.2	20.3	17.1
2013	100.0	43.9	10.3	2.9	23.9	18.9
2014	100.0	40.2	8.9	3.3	27.5	20.1
2015	100.0	39.8	7.5	3.9	29.0	19.8

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

In comparison, the share of renewable energy in the U.S. was relatively stable from 1960 to 2007. Renewable energy consumed before 2007 was mainly hydro and biomass. From 2007 to 2015, the share of renewable energy in the U.S. increased from 6.4% to 9.5%. About 48% of the increase was due to the increased wind energy consumption, 40% due to increased biomass, and 12% due to increased solar.

Table 2.4 Renewable Energy's Share of Total Primary Energy in the U.S.

	Share of Total Primary Energy Consumption (%)					
	Total	Renewable Energy				
Year	Renewable	Biomass	Geothermal	Hydro	Solar*	Wind
1960	6.5	2.9	0.0	3.6	0.0	0.0
1965	6.3	2.5	0.0	3.8	0.0	0.0
1970	6.0	2.1	0.0	3.9	0.0	0.0
1975	6.5	2.1	0.0	4.4	0.0	0.0
1980	6.9	3.2	0.1	3.7	0.0	0.0
1985	8.0	3.9	0.1	3.9	0.0	0.0
1990	7.1	3.2	0.2	3.6	0.1	0.0
1991	7.2	3.3	0.2	3.6	0.1	0.0
1992	6.8	3.4	0.2	3.1	0.1	0.0
1993	7.0	3.3	0.2	3.3	0.1	0.0
1994	6.7	3.4	0.2	3.0	0.1	0.0
1995	7.2	3.4	0.2	3.5	0.1	0.0
1996	7.5	3.4	0.2	3.8	0.1	0.0
1997	7.4	3.3	0.2	3.8	0.1	0.0
1998	6.8	3.1	0.2	3.5	0.1	0.0
1999	6.7	3.1	0.2	3.4	0.1	0.0
2000	6.2	3.0	0.2	2.8	0.1	0.1
2001	5.4	2.7	0.2	2.3	0.1	0.1
2002	5.9	2.8	0.2	2.8	0.1	0.1
2003	6.1	2.9	0.2	2.9	0.1	0.1
2004	6.1	3.0	0.2	2.7	0.1	0.1
2005	6.2	3.1	0.2	2.7	0.1	0.2
2006	6.6	3.2	0.2	2.9	0.1	0.3
2007	6.4	3.4	0.2	2.4	0.1	0.3
2008	7.2	3.9	0.2	2.5	0.1	0.6
2009	8.0	4.1	0.2	2.8	0.1	0.8
2010	8.2	4.3	0.2	2.6	0.1	0.9
2011	9.2	4.4	0.2	3.2	0.1	1.2
2012	9.1	4.5	0.2	2.8	0.2	1.4
2013	9.3	4.6	0.2	2.6	0.2	1.7
2014	9.5	4.7	0.2	2.5	0.3	1.8
2015	9.5	4.6	0.2	2.4	0.4	1.8

* Customer-sited PV included.
Source: Energy Information Administration, State Energy Data System

Table 2.5 U.S. Share of Renewable Energy by Source

	Share of Renewable Energy Consumption (%)					
	Total	Renewable Energy				
Year	Renewable	Biomass	Geothermal	Hydro	Solar*	Wind
1960	100.0	45.1	0.0	54.9	0.0	0.0
1965	100.0	39.3	0.1	60.6	0.0	0.0
1970	100.0	35.2	0.1	64.7	0.0	0.0
1975	100.0	32.0	0.7	67.3	0.0	0.0
1980	100.0	45.6	1.0	53.5	0.0	0.0
1985	100.0	49.6	1.6	48.8	0.0	0.0
1990	100.0	45.3	2.8	50.4	1.0	0.5
1991	100.0	45.8	2.9	49.7	1.0	0.5
1992	100.0	50.4	3.1	45.0	1.1	0.5
1993	100.0	47.8	3.1	47.6	1.1	0.5
1994	100.0	50.6	2.9	44.8	1.1	0.6
1995	100.0	47.3	2.3	48.9	1.0	0.5
1996	100.0	45.0	2.3	51.2	1.0	0.5
1997	100.0	44.3	2.4	51.9	1.0	0.5
1998	100.0	45.1	2.6	50.8	1.0	0.5
1999	100.0	45.5	2.6	50.2	1.0	0.7
2000	100.0	49.3	2.7	46.1	1.0	0.9
2001	100.0	50.9	3.2	43.4	1.2	1.3
2002	100.0	47.1	3.0	47.0	1.0	1.8
2003	100.0	47.2	2.9	47.0	1.0	1.9
2004	100.0	49.5	2.9	44.3	1.0	2.3
2005	100.0	49.8	2.9	43.5	0.9	2.9
2006	100.0	48.9	2.7	43.5	0.9	4.0
2007	100.0	53.1	2.9	37.8	1.0	5.3
2008	100.0	53.4	2.7	35.2	1.0	7.6
2009	100.0	51.5	2.6	35.3	1.0	9.5
2010	100.0	53.0	2.6	31.7	1.1	11.5
2011	100.0	48.3	2.4	34.9	1.2	13.1
2012	100.0	49.5	2.5	30.6	1.8	15.6
2013	100.0	49.2	2.4	28.3	2.5	17.7
2014	100.0	49.4	2.3	26.3	3.6	18.4
2015	100.0	48.8	2.3	25.1	4.6	19.2

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

3. HAWAII'S RENEWABLE ENERGY SOURCES

Renewable energy consumed in Hawaii mainly includes five types of energy: biomass, geothermal, hydro, wind, and solar. Biomass consumed in Hawaii includes W&W and fuel ethanol. Before 2005, all biomass consumed in Hawaii was W&W. Significant W&W was consumed since 1980 and increased until 1989. From 1989 to 2002, W&W consumption decreased 19,504 BBTUs or 72%. W&W consumption since 2002 was relatively stable. Fuel ethanol consumption was started in 2005. From 2005 to 2015, fuel ethanol consumption increased 2,756 BBTUs or 233%. As a result, the ethanol share of total biomass consumption increased from 12% in 2005 to 34% in 2015.

Table 3.1 Hawaii's Biomass Consumption by Source

	Biomass Consumption				
	Biomass	W&W	Ethanol	% of Total Biomas	
Year	BBTUs	BBTUs	BBTUs	W&W	Ethanol
1960	-	-	-		
1965	172	172	-	100	-
1970	429	429	-	100	-
1975	569	569	-	100	-
1980	11,910	11,910	-	100	-
1985	14,217	14,217	-	100	-
1986	16,314	16,314	-	100	-
1987	17,846	17,846	-	100	-
1988	19,426	19,426	-	100	-
1989	26,984	26,984	-	100	-
1990	25,924	25,924	-	100	-
1991	25,446	25,446	-	100	-
1992	24,901	24,901	-	100	-
1993	24,388	24,388	-	100	-
1994	20,724	20,724	-	100	-
1995	19,803	19,803	-	100	-
1996	19,066	19,066	-	100	-
1997	17,433	17,433	-	100	-
1998	16,548	16,548	-	100	-
1999	16,981	16,981	-	100	-
2000	15,194	15,194	-	100	-
2001	7,947	7,947	-	100	-
2002	7,480	7,480	-	100	-
2003	9,305	9,305	-	100	-
2004	9,336	9,336	-	100	-
2005	9,565	8,382	1,183	88	12
2006	9,875	8,524	1,351	86	14
2007	9,693	7,969	1,724	82	18
2008	11,795	8,609	3,185	73	27
2009	12,225	8,586	3,638	70	30
2010	10,448	7,664	2,783	73	27
2011	10,550	7,320	3,230	69	31
2012	9,604	6,672	2,932	69	31
2013	11,179	8,151	3,028	73	27
2014	11,008	7,706	3,303	70	30
2015	11,485	7,545	3,939	66	34

Source: Energy Information Administration, State Energy Data System

Before 1990, Hawaii's W&W was mainly consumed in the industrial sector. From 1990 to 2003, about 30% of W&W was consumed in the electricity sector. Since 2004, the commercial sector replaced the electricity sector became a significant user of W&W. In 2015, the commercial sector accounted for 43% of total W&W consumption in Hawaii; followed by the industrial sector at 42%, the electricity sector at 11%, and the residential sector at 4%.

Table 3.2 Hawaii's Wood and Waste Consumption by Sector

	Wood and Waste Consumption By Sector in BBTUs				Share of Wood and Waste Consumption By Sector in % of W&W Consumption			
Year	Electric	Industrial	Commercial	Residential	Electric	Industrial	Commercial	Residential
1960	-	-	-	-	-	-	-	-
1965	-	172	-	-	-	100	-	-
1970	257	172	-	-	60	40	-	-
1975	259	310	-	-	46	54	-	-
1980	-	11,910	-	-	-	100	-	-
1985	262	13,955	-	-	2	98	-	-
1986	-	16,314	-	-	-	100	-	-
1987	-	17,846	-	-	-	100	-	-
1988	-	19,426	-	-	-	100	-	-
1989	360	26,624	-	-	1	99	-	-
1990	7,765	18,159	-	-	30	70	-	-
1991	7,656	17,790	-	-	30	70	-	-
1992	7,223	17,678	-	-	29	71	-	-
1993	7,631	16,757	-	-	31	69	-	-
1994	6,560	14,164	-	-	32	68	-	-
1995	6,547	13,256	-	-	33	67	-	-
1996	4,921	14,145	-	-	26	74	-	-
1997	5,608	11,825	-	-	32	68	-	-
1998	5,423	11,125	-	-	33	67	-	-
1999	5,410	11,571	-	-	32	68	-	-
2000	5,325	9,869	-	-	35	65	-	-
2001	2,830	5,117	-	-	36	64	-	-
2002	2,398	5,083	-	-	32	68	-	-
2003	2,561	6,745	-	-	28	72	-	-
2004	-	6,795	2,541	-	-	73	27	-
2005	-	5,943	2,264	175	-	71	27	2
2006	-	5,753	2,616	156	-	67	31	2
2007	-	5,447	2,350	172	-	68	29	2
2008	-	5,351	3,066	192	-	62	36	2
2009	44	5,155	3,045	342	1	60	35	4
2010	40	4,381	2,945	298	1	57	38	4
2011	579	3,651	2,785	305	8	50	38	4
2012	403	3,771	2,213	285	6	57	33	4
2013	519	4,025	3,214	393	6	49	39	5
2014	609	3,402	3,294	400	8	44	43	5
2015	853	3,159	3,236	298	11	42	43	4

Source: Energy Information Administration, State Energy Data System

Hawaii's fuel ethanol was almost all consumed in the transportation sector. Only a small amount of ethanol was consumed in the industrial sector and the commercial sector.

Table 3.3Hawaii's Fuel Ethanol Consumption by Sector

	Ethanol Consumption By Sector in BBTUs			Share of Ethanol Consumption By Sector in % of Ethanol Consumption		
Year	Industrial	Commercial	Transportation	Industrial	Commercial	Transportation
1960	-	-	-	-	-	-
1965	-	-	-	-	-	-
1970	-	-	-	-	-	-
1975	-	-	-	-	-	-
1980	-	-	-	-	-	-
1985	-	-	-	-	-	-
1986	-	-	-	-	-	-
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	-	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	-	-	-	-
1992	-	-	-	-	-	-
1993	-	-	-	-	-	-
1994	-	-	-	-	-	-
1995	-	-	-	-	-	-
1996	-	-	-	-	-	-
1997	-	-	-	-	-	-
1998	-	-	-	-	-	-
1999	-	-	-	-	-	-
2000	-	-	-	-	-	-
2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	-	-	-	-	-	-
2004	-	-	-	-	-	-
2005	14	1	1,167	1	0	99
2006	17	1	1,333	1	0	99
2007	37	2	1,685	2	0	98
2008	74	4	3,108	2	0	98
2009	78	4	3,556	2	0	98
2010	40	3	2,740	1	0	98
2011	43	4	3,184	1	0	99
2012	39	3	2,890	1	0	99
2013	39	4	2,985	1	0	99
2014	52	4	3,247	2	0	98
2015	102	111	3,726	3	3	95

Source: Energy Information Administration, State Energy Data System

"0" indicates values rounded less than 0.

Significant geothermal consumption in Hawaii was started in 1993. From 1993 to 2015, geothermal consumption fluctuated between 1,600 to 2,700 BBTUs. In 2015, geothermal consumption was 2,247 BBTUs. Geothermal was almost entirely consumed in the electricity sector.

Table 3.4 Hawaii's Geothermal Consumption by Sector

	Geothermal Consumption By Sector in BBTUs			
Year	Electric	Industrial	Commercial	Residential
1960	-	-	-	-
1965	-	-	-	-
1970	-	-	-	-
1975	-	-	-	-
1980	-	-	-	-
1985	197	-	-	-
1986	184	-	-	-
1987	133	-	-	-
1988	168	-	-	-
1989	147	-	-	-
1990	-	-	-	-
1991	-	-	-	-
1992	22	-	-	-
1993	1,570	-	-	-
1994	1,912	-	-	-
1995	2,418	-	-	-
1996	2,502	-	-	-
1997	2,506	-	-	-
1998	2,418	-	-	-
1999	2,156	2	4	-
2000	2,673	2	6	-
2001	2,135	2	6	-
2002	740	2	6	-
2003	1,805	1	6	-
2004	2,136	2	6	-
2005	2,216	2	7	-
2006	2,106	2	6	-
2007	2,272	2	6	-
2008	2,309	2	5	-
2009	1,636	2	5	-
2010	1,957	2	5	-
2011	2,175	2	6	-
2012	2,484	2	6	-
2013	2,622	2	6	-
2014	2,414	2	6	-
2015	2,147	2	6	-

Source: Energy Information Administration, State Energy Data System

Hawaii's hydro energy consumption was fluctuating around 1,000 BBTUs over time. Hydro energy was consumed in the electricity sector and the industrial sector.

Table 3.5 Hawaii's Hydro Energy Consumption by Sector

	Hydro Energy Consumption By Sector				
	in BBTUs			In % of Hydro	
Year	Total	Electric	Industrial	Electric	Industrial
1960	292	292	-	100.0	-
1965	1,093	229	864	21.0	79.0
1970	1,131	227	904	20.1	79.9
1975	929	190	739	20.5	79.5
1980	898	205	693	22.8	77.2
1985	894	197	697	22.1	78.1
1986	817	121	696	14.8	85.2
1987	855	160	695	18.7	81.3
1988	833	145	688	17.4	82.5
1989	581	234	347	40.3	59.7
1990	828	237	591	28.7	71.5
1991	741	213	528	28.7	71.3
1992	633	102	531	16.1	84.0
1993	580	142	438	24.5	75.5
1994	1,439	649	790	45.1	54.9
1995	1,009	351	658	34.8	65.2
1996	1,075	404	671	37.5	62.4
1997	1,178	496	682	42.1	57.9
1998	1,236	468	768	37.8	62.1
1999	1,175	458	717	39.0	61.0
2000	1,056	441	615	41.8	58.3
2001	1,041	520	521	50.0	50.0
2002	967	354	613	36.6	63.4
2003	917	410	507	44.8	55.3
2004	941	574	367	61.0	39.0
2005	962	623	339	64.8	35.2
2006	1,191	811	380	68.1	31.9
2007	913	540	373	59.1	40.9
2008	831	444	387	53.4	46.6
2009	1,099	754	345	68.6	31.4
2010	687	279	408	40.6	59.4
2011	905	433	472	47.8	52.2
2012	1,091	532	559	48.8	51.3
2013	747	325	422	43.5	56.5
2014	895	397	498	44.4	55.6
2015	1,130	584	546	51.7	48.4

Source: Energy Information Administration, State Energy Data System

Hawaii's solar energy (including customer-sited solar) consumption was started in 1989. From 1989 to 2015, solar energy consumption increased 7,532 BBTUs or 920%. Before 2005, solar energy was mainly consumed in the residential sector. Since 2005, the commercial sector started to consume significant solar energy; and since 2009, the electricity sector started to

consume solar energy. In 2015, the residential sector accounted for 66.7% of total solar energy consumption; followed by the commercial sector at 27.1%, and the electricity sector at 6.1%.

Table 3.6 Hawaii's Solar Energy Consumption by Sector

	Solar Energy Consumption By Sector* in BBTUs					Share of Solar Energy Consumption By Sector in % of Solar Consumption			
Year	Total	Electric	Industrial	Commercial	Residential	Electric	Industrial	Commercial	Residential
1960	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-
1989	819	-	-	1	818	-	-	0.1	99.9
1990	885	-	-	1	883	-	-	0.1	99.8
1991	957	-	-	2	955	-	-	0.2	99.8
1992	1,010	-	-	2	1,008	-	-	0.2	99.8
1993	1,065	-	-	2	1,063	-	-	0.2	99.8
1994	1,120	-	-	2	1,117	-	-	0.2	99.7
1995	1,168	-	1	2	1,165	-	0.1	0.2	99.7
1996	1,211	-	1	3	1,207	-	0.1	0.2	99.7
1997	1,222	-	1	3	1,218	-	0.1	0.2	99.7
1998	1,257	-	1	3	1,253	-	0.1	0.2	99.7
1999	1,280	-	1	4	1,276	-	0.1	0.3	99.7
2000	1,282	-	1	4	1,277	-	0.1	0.3	99.6
2001	1,236	-	1	6	1,230	-	0.1	0.5	99.5
2002	1,240	-	1	6	1,232	-	0.1	0.5	99.4
2003	1,259	-	2	7	1,250	-	0.2	0.6	99.3
2004	1,273	-	2	9	1,261	-	0.2	0.7	99.1
2005	1,301	-	3	14	1,285	-	0.2	1.1	98.8
2006	1,380	-	-	36	1,343	-	-	2.6	97.3
2007	1,516	-	-	74	1,441	-	-	4.9	95.1
2008	1,790	-	-	156	1,634	-	-	8.7	91.3
2009	2,019	14	-	255	1,750	0.7	-	12.6	86.7
2010	2,291	17	-	359	1,915	0.7	-	15.7	83.6
2011	2,828	35	-	595	2,198	1.2	-	21.0	77.7
2012	4,273	44	-	1,209	3,021	1.0	-	28.3	70.7
2013	6,093	186	-	1,634	4,273	3.1	-	26.8	70.1
2014	7,534	373	-	2,168	4,993	5.0	-	28.8	66.3
2015	8,351	507	4	2,267	5,572	6.1	0.0	27.1	66.7

* Including customer-sited solar

Source: Energy Information Administration, State Energy Data System

Hawaii started to consume wind energy in 1989, from 1989 to 2015, wind energy consumption increased from 344 BBTUs to 5,710 BBTUs, increased 5,366 BBTUs or 1,560%. Wind energy was entirely consumed in the electricity sector.

4. HAWAII'S RENEWABLE ENERGY USERS

The U.S. Energy Information Administration (EIA) defined the users of primary energy into five sectors: (1) **Transportation sector:** Consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. (2) **Industrial sector:** Consists of all facilities and equipment used for producing, processing, or assembling goods. (3) **Commercial sector:** Consists of service-providing facilities and equipment of businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. (4) **Residential sector:** Consists of living quarters for private households, and (5) **Electricity sector**: Consists of electricity generation facilities. The first four are end use sectors and the electricity sector generates and provide secondary energy sources.

As shown in Table 4.1, Hawaii's total energy consumption increased from 94,855 BBTUs in 1960 to 321,421 BBTUs in 1990, decreased from 1990 to 2001, increased from 2001 to 2007, and then decreased from 2007 to 2015. From 1960 to 2015, including electricity allocated to the final user sectors, the share of transportation decreased from 65.1% to 51.4%; the share of the commercial sector increased from 5.6% to 14.6%, and the share of the residential sector increased from 7.5% to 11.3%.

Table 4.1 Hawaii's Total Primary Energy Consumption by Sector with Consumption by Electricity Sector Allocated to the End-Use Sectors

		Total Primary Energy Consumption By Sector* in BBTUs				Share of Total Primary Energy Consumption By Sector % of Total Energy Consumption			
Year	Total Energy	Industrial	Commercial	Residential	Transportation	Industrial	Commercial	Residential	Transportation
1960	94,855	20,633	5,300	7,144	61,778	21.8	5.6	7.5	65.1
1965	130,589	34,710	7,024	9,875	78,979	26.6	5.4	7.6	60.5
1970	196,979	43,657	12,519	15,460	125,344	22.2	6.4	7.8	63.6
1975	214,429	50,397	14,533	18,957	130,543	23.5	6.8	8.8	60.9
1980	262,456	74,651	20,073	21,020	146,713	28.4	7.6	8.0	55.9
1985	248,555	67,347	18,392	19,928	142,887	27.1	7.4	8.0	57.5
1990	321,421	98,941	37,211	30,724	154,545	30.8	11.6	9.6	48.1
1991	295,155	89,031	28,809	26,114	151,201	30.2	9.8	8.8	51.2
1992	306,042	93,645	38,613	29,657	144,127	30.6	12.6	9.7	47.1
1993	282,878	92,336	30,736	29,587	130,218	32.6	10.9	10.5	46.0
1994	299,349	93,802	35,024	30,504	140,019	31.3	11.7	10.2	46.8
1995	297,037	93,006	34,606	31,255	138,169	31.3	11.7	10.5	46.5
1996	283,262	95,586	34,034	32,045	121,597	33.7	12.0	11.3	42.9
1997	273,576	88,667	35,502	32,135	117,273	32.4	13.0	11.7	42.9
1998	273,516	80,664	45,894	32,331	114,627	29.5	16.8	11.8	41.9
1999	269,448	78,030	35,961	32,371	123,086	29.0	13.3	12.0	45.7
2000	273,430	77,952	37,281	32,983	125,215	28.5	13.6	12.1	45.8
2001	270,245	69,474	36,571	32,162	132,038	25.7	13.5	11.9	48.9
2002	284,802	70,758	39,354	34,518	140,172	24.8	13.8	12.1	49.2
2003	300,977	68,843	37,507	31,774	162,853	22.9	12.5	10.6	54.1
2004	314,760	68,913	41,259	32,638	171,951	21.9	13.1	10.4	54.6
2005	324,741	72,371	39,901	33,335	179,134	22.3	12.3	10.3	55.2
2006	327,187	71,570	40,677	33,679	181,261	21.9	12.4	10.3	55.4
2007	337,743	69,049	40,238	34,099	194,357	20.4	11.9	10.1	57.5
2008	276,646	65,848	40,856	33,423	136,519	23.8	14.8	12.1	49.3
2009	276,035	69,100	40,669	33,308	132,958	25.0	14.7	12.1	48.2
2010	276,948	67,951	40,096	32,613	136,289	24.5	14.5	11.8	49.2
2011	285,270	67,424	41,093	32,439	144,315	23.6	14.4	11.4	50.6
2012	277,794	65,051	39,155	31,548	142,040	23.4	14.1	11.4	51.1
2013	278,404	65,346	40,633	30,904	141,521	23.5	14.6	11.1	50.8
2014	279,001	64,469	40,999	31,351	142,182	23.1	14.7	11.2	51.0
2015	282,418	64,132	41,260	31,824	145,202	22.7	14.6	11.3	51.4

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

Total energy consumed by the electric power sector, excluding customer-sited solar, increased from 17,603 BBTUs in 1960 to 91,592 BBTUs in 2015. The share of electricity sector energy consumption allocated to the residential sector decreased 12.2 percentage points from 40.0% to 27.8%; the share of commercial sector increased 9.2 percentage points from 23.8% to 33.4%; and the share of the industrial sector increased 2.6 percentage points from 36.2% to 38.9%.

Table 4.2 Hawaii's Electricity Sold and Electrical System Energy Losses by Sector

	Electricity Sold and System Energy Losses By Sector in BBTUs					Share of Electricity Sold and System Losses By Sector in %			
Year	Total	Industrial	Commercial	Residential	Transportation	Industrial	Commercial	Residential	Transportation
1960	17,603	6,374	4,185	7,044	-	36.2	23.8	40.0	-
1965	27,569	12,325	5,564	9,679	-	44.7	20.2	35.1	-
1970	43,176	19,667	8,818	14,691	-	45.6	20.4	34.0	-
1975	58,778	28,093	12,276	18,408	-	47.8	20.9	31.3	-
1980	69,748	33,360	16,107	20,282	-	47.8	23.1	29.1	-
1985	69,758	33,050	16,954	19,755	-	47.4	24.3	28.3	-
1986	72,694	33,487	18,926	20,283	-	46.1	26.0	27.9	-
1987	76,477	34,410	20,347	21,719	-	45.0	26.6	28.4	-
1988	81,734	37,013	21,941	22,781	-	45.3	26.8	27.9	-
1989	86,465	38,795	23,346	24,323	-	44.9	27.0	28.1	-
1990	105,928	47,592	28,715	29,621	-	44.9	27.1	28.0	-
1991	88,716	39,269	24,515	24,933	-	44.3	27.6	28.1	-
1992	99,327	43,679	27,702	27,945	-	44.0	27.9	28.1	-
1993	99,480	43,316	27,800	28,364	-	43.5	27.9	28.5	-
1994	102,276	43,326	29,727	29,224	-	42.4	29.1	28.6	-
1995	105,520	43,674	31,913	29,934	-	41.4	30.2	28.4	-
1996	107,442	44,497	32,291	30,654	-	41.4	30.1	28.5	-
1997	107,306	44,197	32,531	30,577	-	41.2	30.3	28.5	-
1998	105,629	43,198	32,312	30,118	-	40.9	30.6	28.5	-
1999	106,576	42,576	33,449	30,550	-	39.9	31.4	28.7	-
2000	108,477	42,916	34,613	30,947	-	39.6	31.9	28.5	-
2001	105,273	40,776	34,345	30,152	-	38.7	32.6	28.6	-
2002	110,917	42,279	36,138	32,500	-	38.1	32.6	29.3	-
2003	102,737	38,027	34,774	29,935	-	37.0	33.8	29.1	-
2004	104,437	38,314	35,350	30,773	-	36.7	33.8	29.5	-
2005	104,105	38,641	34,209	31,255	-	37.1	32.9	30.0	-
2006	104,704	38,597	34,575	31,530	-	36.9	33.0	30.1	-
2007	105,688	38,583	35,148	31,958	-	36.5	33.3	30.2	-
2008	102,832	37,650	34,647	30,534	-	36.6	33.7	29.7	-
2009	100,257	36,463	33,544	30,250	-	36.4	33.5	30.2	-
2010	98,675	36,179	33,047	29,450	-	36.7	33.5	29.8	-
2011	98,850	36,366	33,422	29,062	-	36.8	33.8	29.4	-
2012	94,780	36,005	31,841	26,935	-	38.0	33.6	28.4	-
2013	92,335	35,203	31,783	25,348	-	38.1	34.4	27.5	-
2014	92,140	35,880	31,136	25,125	-	38.9	33.8	27.3	-
2015	91,592	35,587	30,569	25,435	-	38.9	33.4	27.8	-

Source: Energy Information Administration, State Energy Data System

Table 4.3 shows Hawaii's total primary energy consumption by five sectors, with the energy consumption of the four final user sectors excluding the electricity allocated to the sector. Energy consumption of the electricity sector, excluding customer-sited solar, was separated in an independent sector. From 1960 to 2015, the share of the electricity sector increased 13.9 percentage points from 18.6% to 32.4%; the share of commercial sector increased 2.6 percentage points from 1.2% to 3.8%; the share of the residential sector increased 2.2 percentage points from 0.1% to 2.3%; the share of the transportation sector decreased 13.7 percentage points from 65.1% to 51.4%; and the share of the industrial sector decreased 4.9 percentage points from 15.0% to 10.1%.

Table 4.3 Hawaii's Total Primary Energy Consumption by Sector with Electricity Sector Separated

		Total Primary Energy Consumption By Sector in BBTUs					Share of Total Primary Energy Consumption By Sector % of Total Primary Energy Consumption				
Year	Total Energy	Industrial	Commercial*	Residential*	Transportation	Electric	Industrial	Commercial*	Residential*	Transportation	Electric
1960	94,855	14,259	1,115	100	61,778	17,603	15.0	1.2	0.1	65.1	18.6
1965	130,589	22,385	1,460	196	78,979	27,568	17.1	1.1	0.2	60.5	21.1
1970	196,979	23,990	3,701	769	125,344	43,176	12.2	1.9	0.4	63.6	21.9
1975	214,429	22,304	2,257	549	130,543	58,778	10.4	1.1	0.3	60.9	27.4
1980	262,456	41,291	3,966	738	146,713	69,749	15.7	1.5	0.3	55.9	26.6
1985	248,555	34,297	1,438	173	142,887	69,758	13.8	0.6	0.1	57.5	28.1
1990	321,421	51,349	8,496	1,103	154,545	105,928	16.0	2.6	0.3	48.1	33.0
1991	295,155	49,762	4,294	1,181	151,201	88,716	16.9	1.5	0.4	51.2	30.1
1992	306,042	49,966	10,911	1,712	144,127	99,327	16.3	3.6	0.6	47.1	32.5
1993	282,878	49,020	2,936	1,223	130,218	99,480	17.3	1.0	0.4	46.0	35.2
1994	299,349	50,476	5,297	1,280	140,019	102,276	16.9	1.8	0.4	46.8	34.2
1995	297,037	49,332	2,693	1,321	138,169	105,520	16.6	0.9	0.4	46.5	35.5
1996	283,262	51,089	1,743	1,391	121,597	107,442	18.0	0.6	0.5	42.9	37.9
1997	273,576	44,470	2,971	1,558	117,273	107,306	16.3	1.1	0.6	42.9	39.2
1998	273,516	37,466	13,582	2,213	114,627	105,628	13.7	5.0	0.8	41.9	38.6
1999	269,448	35,454	2,512	1,821	123,086	106,576	13.2	0.9	0.7	45.7	39.6
2000	273,430	35,036	2,668	2,036	125,215	108,477	12.8	1.0	0.7	45.8	39.7
2001	270,245	28,698	2,226	2,010	132,038	105,273	10.6	0.8	0.7	48.9	39.0
2002	284,802	28,479	3,216	2,018	140,172	110,917	10.0	1.1	0.7	49.2	38.9
2003	300,977	30,816	2,733	1,839	162,853	102,736	10.2	0.9	0.6	54.1	34.1
2004	314,760	30,599	5,909	1,865	171,951	104,437	9.7	1.9	0.6	54.6	33.2
2005	324,741	33,730	5,692	2,080	179,134	104,105	10.4	1.8	0.6	55.2	32.1
2006	327,187	32,973	6,102	2,149	181,261	104,703	10.1	1.9	0.7	55.4	32.0
2007	337,743	30,466	5,090	2,141	194,357	105,688	9.0	1.5	0.6	57.5	31.3
2008	276,646	28,198	6,209	2,889	136,519	102,831	10.2	2.2	1.0	49.3	37.2
2009	276,035	32,637	7,125	3,058	132,958	100,256	11.8	2.6	1.1	48.2	36.3
2010	276,948	31,772	7,049	3,163	136,289	98,675	11.5	2.5	1.1	49.2	35.6
2011	285,270	31,058	7,671	3,377	144,315	98,850	10.9	2.7	1.2	50.6	34.7
2012	277,794	29,046	7,314	4,613	142,040	94,780	10.5	2.6	1.7	51.1	34.1
2013	278,404	30,143	8,850	5,556	141,521	92,335	10.8	3.2	2.0	50.8	33.2
2014	279,001	28,589	9,863	6,226	142,182	92,140	10.2	3.5	2.2	51.0	33.0
2015	282,418	28,545	10,691	6,389	145,202	91,592	10.1	3.8	2.3	51.4	32.4

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

Table 4.4 shows Hawaii's total renewable energy consumption by five sectors. Significant renewable energy was consumed since 1980. From 1980 to 2015, the electricity sector's share of total renewable energy consumption increased 32.4 percentage points from 1.6% to 34.0%; the residential sector's share increased 20.4 percentage points from 0.0% to 20.4%; the commercial sector's share increased 19.5 percentage points from 0.0% to 19.5%; the transportation sector's share increased 12.9 percentage points from 0.0% to 12.9%; and the industrial sector's share decreased 85.2 percentage points from 98.4% to 13.2%.

Table 4.4 Hawaii's Renewable Energy Consumption by Sector

		Total Renewable Energy Consumption By Sector in BBTUs					Share of Renewable Energy Consumption By Sector % of Total Renewable Energy Consumption				
Year	Total Renewable	Industrial	Commercial*	Residential*	Transportation	Electric	Industrial	Commercial*	Residential*	Transportation	Electric
1960	292	-	-	-	-	292	-	-	-	-	100.0
1965	1,265	1,036	-	-	-	229	81.9	-	-	-	18.1
1970	1,559	1,076	-	-	-	484	69.0	-	-	-	31.0
1975	1,498	1,049	-	-	-	449	70.0	-	-	-	30.0
1980	12,808	12,603	-	-	-	205	98.4	-	-	-	1.6
1985	15,307	14,652	-	-	-	656	95.7	-	-	-	4.3
1986	17,315	17,010	-	-	-	305	98.2	-	-	-	1.8
1987	18,834	18,541	-	-	-	293	98.4	-	-	-	1.6
1988	20,427	20,114	-	-	-	313	98.5	-	-	-	1.5
1989	28,875	26,971	1	818	-	1,085	93.4	0.0	2.8	-	3.8
1990	27,937	18,750	1	883	-	8,302	67.1	0.0	3.2	-	29.7
1991	27,516	18,318	2	955	-	8,241	66.6	0.0	3.5	-	29.9
1992	26,800	18,209	2	1,008	-	7,582	67.9	0.0	3.8	-	28.3
1993	27,829	17,195	2	1,063	-	9,569	61.8	0.0	3.8	-	34.4
1994	25,404	14,954	2	1,117	-	9,331	58.9	0.0	4.4	-	36.7
1995	24,608	13,915	2	1,165	-	9,526	56.5	0.0	4.7	-	38.7
1996	24,088	14,817	3	1,207	-	8,060	61.5	0.0	5.0	-	33.5
1997	22,502	12,508	3	1,218	-	8,774	55.6	0.0	5.4	-	39.0
1998	21,657	11,894	3	1,253	-	8,506	54.9	0.0	5.8	-	39.3
1999	21,767	12,291	8	1,276	-	8,193	56.5	0.0	5.9	-	37.6
2000	20,386	10,487	10	1,277	-	8,612	51.4	0.0	6.3	-	42.2
2001	12,389	5,641	12	1,230	-	5,507	45.5	0.1	9.9	-	44.5
2002	10,452	5,699	12	1,232	-	3,508	54.5	0.1	11.8	-	33.6
2003	13,310	7,255	13	1,250	-	4,792	54.5	0.1	9.4	-	36.0
2004	13,769	7,166	2,556	1,261	-	2,785	52.0	18.6	9.2	-	20.2
2005	14,119	6,301	2,286	1,460	1,167	2,905	44.6	16.2	10.3	8.3	20.6
2006	15,350	6,152	2,659	1,499	1,333	3,707	40.1	17.3	9.8	8.7	24.1
2007	16,755	5,859	2,432	1,613	1,685	5,166	35.0	14.5	9.6	10.1	30.8
2008	19,097	5,814	3,231	1,826	3,108	5,118	30.4	16.9	9.6	16.3	26.8
2009	19,440	5,580	3,309	2,092	3,556	4,902	28.7	17.0	10.8	18.3	25.2
2010	17,937	4,831	3,312	2,213	2,740	4,840	26.9	18.5	12.3	15.3	27.0
2011	19,778	4,168	3,390	2,503	3,184	6,533	21.1	17.1	12.7	16.1	33.0
2012	21,058	4,371	3,431	3,306	2,890	7,062	20.8	16.3	15.7	13.7	33.5
2013	25,451	4,488	4,858	4,666	2,985	8,454	17.6	19.1	18.3	11.7	33.2
2014	27,362	3,954	5,472	5,393	3,247	9,296	14.5	20.0	19.7	11.9	34.0
2015	28,830	3,813	5,620	5,870	3,726	9,801	13.2	19.5	20.4	12.9	34.0

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

Table 4.5 shows the share of renewable energy consumption by five sectors. Before 1989, only the industrial sector consumed a significant share of renewable energy; however, the share of renewable energy in the industrial sector decreased substantially since 1989. Since 1989, renewable energy (including customer-sited solar) became the dominant energy source in the residential sector. Since 2004, renewable energy also became a major source of energy in the commercial sector. The share of renewable energy in the electricity sector increased from 1960 to 1993, decreased from 1993 to 2004, and increased from 2.67% in 2004 to 10.70% in 2015.

Table 4.5 Hawaii's Share of Renewable Energy Consumption by Sector

		Share of Renewable Energy Consumption By Sector in % of Total Primary Energy Consumption				
Year	Total Renewable	Industrial	Commercial*	Residential*	Transportation	Electric
1960	0.31	-	-	-	-	1.66
1965	0.97	4.63	-	-	-	0.83
1970	0.79	4.49	-	-	-	1.12
1975	0.70	4.70	-	-	-	0.76
1980	4.88	30.52	-	-	-	0.29
1985	6.16	42.72	-	-	-	0.94
1986	7.06	39.21	-	-	-	0.42
1987	7.55	41.04	-	-	-	0.38
1988	7.05	38.85	-	-	-	0.38
1989	9.32	49.04	0.01	77.39	-	1.25
1990	8.69	36.51	0.01	80.05	-	7.84
1991	9.32	36.81	0.05	80.86	-	9.29
1992	8.76	36.44	0.02	58.88	-	7.63
1993	9.84	35.08	0.07	86.92	-	9.62
1994	8.49	29.63	0.04	87.27	-	9.12
1995	8.28	28.21	0.07	88.19	-	9.03
1996	8.50	29.00	0.17	86.77	-	7.50
1997	8.23	28.13	0.10	78.18	-	8.18
1998	7.92	31.75	0.02	56.62	-	8.05
1999	8.08	34.67	0.32	70.07	-	7.69
2000	7.46	29.93	0.37	62.72	-	7.94
2001	4.58	19.66	0.54	61.19	-	5.23
2002	3.67	20.01	0.37	61.05	-	3.16
2003	4.42	23.54	0.48	67.97	-	4.66
2004	4.37	23.42	43.26	67.61	-	2.67
2005	4.35	18.68	40.16	70.19	0.65	2.79
2006	4.69	18.66	43.58	69.75	0.74	3.54
2007	4.96	19.23	47.78	75.34	0.87	4.89
2008	6.90	20.62	52.04	63.21	2.28	4.98
2009	7.04	17.10	46.44	68.41	2.67	4.89
2010	6.48	15.21	46.99	69.97	2.01	4.90
2011	6.93	13.42	44.19	74.12	2.21	6.61
2012	7.58	15.05	46.91	71.67	2.03	7.45
2013	9.14	14.89	54.89	83.98	2.11	9.16
2014	9.81	13.83	55.48	86.62	2.28	10.09
2015	10.21	13.36	52.57	91.88	2.57	10.70

* Customer-sited PV included.
Source: Energy Information Administration, State Energy Data System

Table 4.6 shows the renewable energy consumption by source in the industrial sector. From 1960 to 1989, the share of renewable in the industrial sector increased from 0.0% to 28.8%, However, from 1989 to 2015, the share of renewable energy decreased from 28.8% to 5.9%. From 1989 to 2015, among the five types of renewable energy sources consumed in the industrial sector, the share of W&W decreased from 98.7% to 82.8%, the share of hydro increased from 1.3% to 14.3%, and the share of ethanol increased from 0.0% to 2.7%.

Table 4.6 Industrial Sector Renewable Energy Consumption by Source

	Industrial Sector Energy Consumption By Source Units: Billion Btu							Renewable % of	Share of Industrial Sector Renewable Energy By Source % of Industrial Renewable Energy Consumption				
Year	Primary Energy	Total Renewable	Wood and Waste	Ethanol	Geothermal	Hydro	Solar	Primary Energy	Wood and Waste	Ethanol	Geothermal	Hydro	Solar
1960	20,633	-	-	-	-	-	-	-	-	-	-	-	-
1965	34,710	1,036	172	-	-	864	-	3.0	16.6	-	-	83.4	-
1970	43,657	1,076	172	-	-	904	-	2.5	16.0	-	-	84.0	-
1975	50,397	1,049	310	-	-	739	-	2.1	29.6	-	-	70.4	-
1980	74,651	12,603	11,910	-	-	693	-	16.9	94.5	-	-	5.5	-
1985	67,347	14,652	13,955	-	-	697	-	21.8	95.2	-	-	4.8	-
1986	76,868	17,010	16,314	-	-	696	-	22.1	95.9	-	-	4.1	-
1987	79,591	18,541	17,846	-	-	695	-	23.3	96.3	-	-	3.7	-
1988	88,782	20,114	19,426	-	-	688	-	22.7	96.6	-	-	3.4	-
1989	93,795	26,971	26,624	-	-	347	-	28.8	98.7	-	-	1.3	-
1990	98,941	18,750	18,159	-	-	591	-	19.0	96.8	-	-	3.2	-
1991	89,031	18,318	17,790	-	-	528	-	20.6	97.1	-	-	2.9	-
1992	93,645	18,209	17,678	-	-	531	-	19.4	97.1	-	-	2.9	-
1993	92,336	17,195	16,757	-	-	438	-	18.6	97.5	-	-	2.5	-
1994	93,802	14,954	14,164	-	-	790	-	15.9	94.7	-	-	5.3	-
1995	93,006	13,915	13,256	-	-	658	1	15.0	95.3	-	-	4.7	0.0
1996	95,586	14,817	14,145	-	-	671	1	15.5	95.5	-	-	4.5	0.0
1997	88,667	12,508	11,825	-	-	682	1	14.1	94.5	-	-	5.5	0.0
1998	80,664	11,894	11,125	-	-	768	1	14.7	93.5	-	-	6.5	0.0
1999	78,030	12,291	11,571	-	2	717	1	15.8	94.1	-	0.0	5.8	0.0
2000	77,952	10,487	9,869	-	2	615	1	13.5	94.1	-	0.0	5.9	0.0
2001	69,474	5,641	5,117	-	2	521	1	8.1	90.7	-	0.0	9.2	0.0
2002	70,758	5,699	5,083	-	2	613	1	8.1	89.2	-	0.0	10.8	0.0
2003	68,843	7,255	6,745	-	1	507	2	10.5	93.0	-	0.0	7.0	0.0
2004	68,913	7,166	6,795	-	2	367	2	10.4	94.8	-	0.0	5.1	0.0
2005	72,371	6,301	5,943	14	2	339	3	8.7	94.3	0.2	0.0	5.4	0.0
2006	71,570	6,152	5,753	17	2	380	-	8.6	93.5	0.3	0.0	6.2	-
2007	69,049	5,859	5,447	37	2	373	-	8.5	93.0	0.6	0.0	6.4	-
2008	65,848	5,814	5,351	74	2	387	-	8.8	92.0	1.3	0.0	6.7	-
2009	69,100	5,580	5,155	78	2	345	-	8.1	92.4	1.4	0.0	6.2	-
2010	67,951	4,831	4,381	40	2	408	-	7.1	90.7	0.8	0.0	8.4	-
2011	67,424	4,168	3,651	43	2	472	-	6.2	87.6	1.0	0.0	11.3	-
2012	65,051	4,371	3,771	39	2	559	-	6.7	86.3	0.9	0.0	12.8	-
2013	65,346	4,488	4,025	39	2	422	-	6.9	89.7	0.9	0.0	9.4	-
2014	64,469	3,954	3,402	52	2	498	-	6.1	86.0	1.3	0.1	12.6	-
2015	64,132	3,813	3,159	102	2	546	4	5.9	82.8	2.7	0.1	14.3	0.1

Source: Energy Information Administration, State Energy Data System

Table 4.7 shows the renewable energy consumption by source in the commercial sector. Before 2004, renewable energy consumption in the commercial sector was very limited. Since 2004, the commercial sector started to consume W&W and solar. From 2003 to 2015, the share of renewable in the commercial sector increased from 0.0% to 13.6%. From 2004 to 2015, among the four types of renewable energy sources consumed in the commercial sector, the share of W&W decreased from 99.4% to 57.6%, and the share of solar increased from 0.4% to 40.3%.

Table 4.7 Commercial Sector Renewable Energy Consumption by Source

	Commercial Sector Energy Consumption By Source Units: Billion Btu						Renewable % of	Share of Commercial Sector Renewable Energy By Source % of Commercial Renewable Energy Consumption			
Year	Primary Energy	Total Renewable	Wood and Waste	Ethanol	Geothermal	Solar*	Primary Energy	Wood and Waste	Ethanol	Geothermal	Solar*
1989	36,094	1	-	-	-	1	0.0	-	-	-	100.0
1990	37,211	1	-	-	-	1	0.0	-	-	-	100.0
1991	28,809	2	-	-	-	2	0.0	-	-	-	100.0
1992	38,613	2	-	-	-	2	0.0	-	-	-	100.0
1993	30,736	2	-	-	-	2	0.0	-	-	-	100.0
1994	35,024	2	-	-	-	2	0.0	-	-	-	100.0
1995	34,606	2	-	-	-	2	0.0	-	-	-	100.0
1996	34,034	3	-	-	-	3	0.0	-	-	-	100.0
1997	35,502	3	-	-	-	3	0.0	-	-	-	100.0
1998	45,894	3	-	-	-	3	0.0	-	-	-	100.0
1999	35,961	8	-	-	4	4	0.0	-	-	50.0	50.0
2000	37,281	10	-	-	6	4	0.0	-	-	60.0	40.0
2001	36,571	12	-	-	6	6	0.0	-	-	50.0	50.0
2002	39,354	12	-	-	6	6	0.0	-	-	50.0	50.0
2003	37,507	13	-	-	6	7	0.0	-	-	46.2	53.8
2004	41,259	2,556	2,541	-	6	9	6.2	99.4	-	0.2	0.4
2005	39,901	2,286	2,264	1	7	14	5.7	99.0	0.0	0.3	0.6
2006	40,677	2,659	2,616	1	6	36	6.5	98.4	0.0	0.2	1.4
2007	40,238	2,432	2,350	2	6	74	6.0	96.6	0.1	0.2	3.0
2008	40,856	3,231	3,066	4	5	156	7.9	94.9	0.1	0.2	4.8
2009	40,669	3,309	3,045	4	5	255	8.1	92.0	0.1	0.2	7.7
2010	40,096	3,312	2,945	3	5	359	8.3	88.9	0.1	0.2	10.8
2011	41,093	3,390	2,785	4	6	595	8.2	82.2	0.1	0.2	17.6
2012	39,155	3,431	2,213	3	6	1,209	8.8	64.5	0.1	0.2	35.2
2013	40,633	4,858	3,214	4	6	1,634	12.0	66.2	0.1	0.1	33.6
2014	40,999	5,472	3,294	4	6	2,168	13.3	60.2	0.1	0.1	39.6
2015	41,260	5,620	3,236	111	6	2,267	13.6	57.6	2.0	0.1	40.3

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

Table 4.8 shows the renewable energy consumption by source in the residential sector. Before 1989, there were no renewable energy consumption in the residential sector. Since 1989, the residential sector started to consume solar. Since 2005, a small amount of W&W was consumed in the residential sector. From 1989 to 2015, the share of renewable in the residential sector increased from 3.2% to 18.4%; total renewable energy consumption in the residential sector increased 5,052 BBTUs, about 94.1% or 4,754 BBTUs were from solar, the rest were from wood.

Table 4.8 Residential Sector Renewable Energy Consumption by Source

	Residential Sector Energy Consumption By Source Units: Billion Btu					Renewable % of	Share of Residential Sector Renewable Energy By Source % of Residential Renewable Energy Consumption		
Year	Primary Energy	Total Renewable	W&W	Geothermal	Solar*	Primary Energy	W&W	Geothermal	Solar*
1989	25,380	818	-	-	818	3.2	-	-	100.0
1990	30,724	883	-	-	883	2.9	-	-	100.0
1991	26,114	955	-	-	955	3.7	-	-	100.0
1992	29,657	1,008	-	-	1,008	3.4	-	-	100.0
1993	29,587	1,063	-	-	1,063	3.6	-	-	100.0
1994	30,504	1,117	-	-	1,117	3.7	-	-	100.0
1995	31,255	1,165	-	-	1,165	3.7	-	-	100.0
1996	32,045	1,207	-	-	1,207	3.8	-	-	100.0
1997	32,135	1,218	-	-	1,218	3.8	-	-	100.0
1998	32,331	1,253	-	-	1,253	3.9	-	-	100.0
1999	32,371	1,276	-	-	1,276	3.9	-	-	100.0
2000	32,983	1,277	-	-	1,277	3.9	-	-	100.0
2001	32,162	1,230	-	-	1,230	3.8	-	-	100.0
2002	34,518	1,232	-	-	1,232	3.6	-	-	100.0
2003	31,774	1,250	-	-	1,250	3.9	-	-	100.0
2004	32,638	1,261	-	-	1,261	3.9	-	-	100.0
2005	33,335	1,460	175	-	1,285	4.4	12.0	-	88.0
2006	33,679	1,499	156	-	1,343	4.5	10.4	-	89.6
2007	34,099	1,613	172	-	1,441	4.7	10.7	-	89.3
2008	33,423	1,826	192	-	1,634	5.5	10.5	-	89.5
2009	33,308	2,092	342	-	1,750	6.3	16.3	-	83.7
2010	32,613	2,213	298	-	1,915	6.8	13.5	-	86.5
2011	32,439	2,503	305	-	2,198	7.7	12.2	-	87.8
2012	31,548	3,306	285	-	3,021	10.5	8.6	-	91.4
2013	30,904	4,666	393	-	4,273	15.1	8.4	-	91.6
2014	31,351	5,393	400	-	4,993	17.2	7.4	-	92.6
2015	31,824	5,870	298	-	5,572	18.4	5.1	-	94.9

* Customer-sited PV included.

Source: Energy Information Administration, State Energy Data System

According to the EIA data, renewable energy consumed in the transportation sector only includes ethanol. The energy consumption of electric vehicles was not included in the EIA data. Hawaii started to consume ethanol in 2005. From 2005 to 2015, ethanol consumption in the transportation sector increased from 1,167 BBTUs to 3,726 BBTUs. As a result, the share of renewable energy in the transportation sector increased from 0.7% to 2.6%.

Table 4.9 Transportation Sector Renewable Energy Consumption by Source

	Transportation Sector Energy Consumption Units: Billion Btu			Renewable % of Primary Energy
Year	Primary Energy	Total Renewable	Ethanol	
2005	179,134	1,167	1,167	0.7
2006	181,261	1,333	1,333	0.7
2007	194,357	1,685	1,685	0.9
2008	136,519	3,108	3,108	2.3
2009	132,958	3,556	3,556	2.7
2010	136,289	2,740	2,740	2.0
2011	144,315	3,184	3,184	2.2
2012	142,040	2,890	2,890	2.0
2013	141,521	2,985	2,985	2.1
2014	142,182	3,247	3,247	2.3
2015	145,202	3,726	3,726	2.6

Source: Energy Information Administration, State Energy Data System

Table 4.10 shows the renewable energy consumption of the electricity sector (excluding customer-sited solar). Before 1989, renewable energy consumption in the electricity sector was very limited. From 1990 to 2003, significant amount of W&W was used to generate electricity. Since 1993, significant amount of geothermal was used to generate electricity, and wind started to play an important role since 2007. As a result, the share of renewable energy in the electricity sector increased from 0.4% in 1988 to 10.7% in 2015.

Table 4.10 Electric Power Sector Renewable Energy Consumption by Source

	Electric Power Sector Energy Consumption By Source Units: Billion Btu							Renewable % of Primary Energy
Year	Primary Energy	Total Renewable	Wood and Waste	Geothermal	Hydro	Wind	Solar*	
1988	81,734	313	-	168	145	-	-	0.4
1989	86,465	1,085	360	147	234	344	-	1.3
1990	105,928	8,302	7,765	-	237	300	-	7.8
1991	88,716	8,241	7,656	-	213	372	-	9.3
1992	99,327	7,582	7,223	22	102	235	-	7.6
1993	99,480	9,569	7,631	1,570	142	226	-	9.6
1994	102,276	9,331	6,560	1,912	649	210	-	9.1
1995	105,520	9,526	6,547	2,418	351	210	-	9.0
1996	107,442	8,060	4,921	2,502	404	233	-	7.5
1997	107,306	8,774	5,608	2,506	496	164	-	8.2
1998	105,628	8,506	5,423	2,418	468	197	-	8.1
1999	106,576	8,193	5,410	2,156	458	169	-	7.7
2000	108,477	8,612	5,325	2,673	441	173	-	7.9
2001	105,273	5,507	2,830	2,135	520	22	-	5.2
2002	110,917	3,508	2,398	740	354	16	-	3.2
2003	102,736	4,792	2,561	1,805	410	16	-	4.7
2004	104,437	2,785	-	2,136	574	75	-	2.7
2005	104,105	2,905	-	2,216	623	66	-	2.8
2006	104,703	3,707	-	2,106	811	790	-	3.5
2007	105,688	5,166	-	2,272	540	2,354	-	4.9
2008	102,831	5,118	-	2,309	444	2,365	-	5.0
2009	100,256	4,902	44	1,636	754	2,454	14	4.9
2010	98,675	4,840	40	1,957	279	2,547	17	4.9
2011	98,850	6,533	579	2,175	433	3,311	35	6.6
2012	94,780	7,062	403	2,484	532	3,599	44	7.5
2013	92,335	8,454	519	2,622	325	4,802	186	9.2
2014	92,140	9,296	609	2,414	397	5,503	373	10.1
2015	91,592	9,801	853	2,147	584	5,710	507	10.7

* Does not include customer-sited PV.

Source: Energy Information Administration, State Energy Data System

Table 4.11 shows the shares of renewable energy consumption by source in the electricity sector. In 2015, wind accounted for 58.3% of total renewable consumption in the electricity sector; followed by geothermal at 21.9%, W&W at 8.7%, hydro at 6.0%, and solar at 5.2%.

Table 4.11 Share of Electric Power Sector Renewable Energy Consumption by Source

	Electric Power Sector Renewable Energy Consumption By Source % of Renewable Energy Consumption				
Year	Wood and Waste	Geothermal	Hydro	Wind	Solar*
1988	-	53.7	46.3	-	-
1989	33.2	13.5	21.6	31.7	-
1990	93.5	-	2.9	3.6	-
1991	92.9	-	2.6	4.5	-
1992	95.3	0.3	1.3	3.1	-
1993	79.7	16.4	1.5	2.4	-
1994	70.3	20.5	7.0	2.3	-
1995	68.7	25.4	3.7	2.2	-
1996	61.1	31.0	5.0	2.9	-
1997	63.9	28.6	5.7	1.9	-
1998	63.8	28.4	5.5	2.3	-
1999	66.0	26.3	5.6	2.1	-
2000	61.8	31.0	5.1	2.0	-
2001	51.4	38.8	9.4	0.4	-
2002	68.4	21.1	10.1	0.5	-
2003	53.4	37.7	8.6	0.3	-
2004	-	76.7	20.6	2.7	-
2005	-	76.3	21.4	2.3	-
2006	-	56.8	21.9	21.3	-
2007	-	44.0	10.5	45.6	-
2008	-	45.1	8.7	46.2	-
2009	0.9	33.4	15.4	50.1	0.3
2010	0.8	40.4	5.8	52.6	0.4
2011	8.9	33.3	6.6	50.7	0.5
2012	5.7	35.2	7.5	51.0	0.6
2013	6.1	31.0	3.8	56.8	2.2
2014	6.6	26.0	4.3	59.2	4.0
2015	8.7	21.9	6.0	58.3	5.2

* Does not include customer-sited PV.

Source: Energy Information Administration, State Energy Data System

5. HAWAII'S RENEWABLE ELECTRICITY

Table 5.1 shows the electricity generated by renewable energy sources in GWh by the electric power industry, excluding the electricity generated from customer-sited solar systems. According to the EIA electricity data, from 1990 to 2002, the renewable energy generated electricity share of total electricity generation decreased from 9.8% to 5.2%. From 2002 to 2016, the share of renewable increased from 5.2% to 17.7%. The decrease from 1990 to 2002 was mainly due to decreased W&W generated electricity; and the increase from 2002 to 2016 was mainly due to increased wind and solar generated electricity.

Table 5.1 Electric Power Sector Renewable Electricity by Source

	Net Generation of Electricity By Selected Renewable Energy Units: GWh							Total Net Electricity Generation	% of Selected Renewable in Total Net
Year	Biomass	Geothermal	Hydro	Wind	Solar*	Others**	Sum	GWh	Generation
1990	840	-	80	29	-	-	948	9,703	9.8
1991	823	-	71	36	-	-	930	8,703	10.7
1992	805	2	61	23	-	-	891	9,844	9.1
1993	777	152	56	22	-	-	1,008	9,944	10.1
1994	730	185	139	20	-	-	1,076	10,109	10.6
1995	640	235	98	20	-	2	994	10,304	9.7
1996	593	242	104	23	-	-	961	10,628	9.0
1997	606	245	115	16	-	-	983	10,312	9.5
1998	504	237	121	19	-	-	882	10,228	8.6
1999	577	211	115	16	-	-	919	10,404	8.8
2000	538	262	103	17	-	-	921	10,593	8.7
2001	288	207	101	2	-	169	767	10,633	7.2
2002	297	73	95	2	-	143	609	11,663	5.2
2003	347	178	91	2	-	172	789	10,976	7.2
2004	329	213	94	7	-	171	814	11,410	7.1
2005	310	222	96	7	-	149	783	11,523	6.8
2006	326	212	120	80	-	176	913	11,559	7.9
2007	285	230	92	238	-	149	995	11,533	8.6
2008	302	234	84	240	0	159	1,020	11,376	9.0
2009	284	168	113	251	1	381	1,199	11,011	10.9
2010	283	201	70	261	2	364	1,181	10,836	10.9
2011	313	224	93	341	4	366	1,340	10,723	12.5
2012	281	261	115	378	5	363	1,402	10,469	13.4
2013	329	275	78	503	19	394	1,599	10,267	15.6
2014	334	254	94	579	39	405	1,705	10,204	16.7
2015	321	230	121	613	54	369	1,709	10,120	16.9
2016	359	260	91	639	89	322	1,760	9,949	17.7

Source: Energy Information Administration, Electricity, Detailed State Data

* Does not include customer-sited PV.

** Including non-biogenic municipal solid waste.

As shown in Table 5.2, from 1990 to 2002, the biomass generated electricity share of total renewable electricity generated decreased from 89% to 49%; the share of geothermal increased from 0% to 12%; the share of hydro increased from 8% to 16%; the share of wind decreased from 3% to 0%; and the share of others (mainly non-biogenic municipal solid waste) increased from 0% to 24%. From 2002 to 2016, the share of biomass decreased further from 49% to 20%; the share of geothermal increased slightly to 15%; the share of hydro decreased to 5%; the share of wind increased to 36%; the share of solar increased to 5%; and the share of others decreased to 18%.

Table 5.2 Share of Electric Power Sector Renewable Electricity by Source

	% of Electricity Net Generation By Selected Renewable Energy Units: % of Total Renewable Electricity						
Year	Biomass	Geothermal	Hydro	Wind	Solar*	Others**	Total
1990	89%	0%	8%	3%	0%	0%	100%
1991	89%	0%	8%	4%	0%	0%	100%
1992	90%	0%	7%	3%	0%	0%	100%
1993	77%	15%	6%	2%	0%	0%	100%
1994	68%	17%	13%	2%	0%	0%	100%
1995	64%	24%	10%	2%	0%	0%	100%
1996	62%	25%	11%	2%	0%	0%	100%
1997	62%	25%	12%	2%	0%	0%	100%
1998	57%	27%	14%	2%	0%	0%	100%
1999	63%	23%	13%	2%	0%	0%	100%
2000	58%	28%	11%	2%	0%	0%	100%
2001	38%	27%	13%	0%	0%	22%	100%
2002	49%	12%	16%	0%	0%	24%	100%
2003	44%	23%	11%	0%	0%	22%	100%
2004	40%	26%	12%	1%	0%	21%	100%
2005	40%	28%	12%	1%	0%	19%	100%
2006	36%	23%	13%	9%	0%	19%	100%
2007	29%	23%	9%	24%	0%	15%	100%
2008	30%	23%	8%	24%	0%	16%	100%
2009	24%	14%	9%	21%	0%	32%	100%
2010	24%	17%	6%	22%	0%	31%	100%
2011	23%	17%	7%	25%	0%	27%	100%
2012	20%	19%	8%	27%	0%	26%	100%
2013	21%	17%	5%	31%	1%	25%	100%
2014	20%	15%	6%	34%	2%	24%	100%
2015	19%	13%	7%	36%	3%	22%	100%
2016	20%	15%	5%	36%	5%	18%	100%

Source: Energy Information Administration, Electricity, Detailed State Data

* Does not include customer-sited PV.

** Including non-biogenic municipal solid waste.

Based on the utility RPS and MFR, the renewable net generation share of total electricity sold can be calculated. This share is used to compare with the RPS target. As shown in Table 5.3, based on the RPS data, renewable electricity net generation accounted for about 26.6% of total electricity sold in 2016.

Table 5.3Total Renewable Electricity Net Generation in Hawaii

	Renewable Electricity Net Generation (GWH)									
Year	Biomass	Biofuels	Geothermal	Hydro	Wind	Solar	Solar Cus*	Total	Total Sold	% of Renewable
2005	403	0	221	82	7	-	2	716	10,539	6.8%
2006	470	0	212	97	82	-	4	865	10,568	8.2%
2007	392	1	230	72	242	-	8	945	10,585	8.9%
2008	413	2	234	78	237	-	12	976	10,390	9.4%
2009	399	5	168	107	250	1	33	963	10,126	9.5%
2010	359	3	202	70	261	2	53	950	10,013	9.5%
2011	365	59	233	90	344	4	90	1,186	9,962	11.9%
2012	342	23	266	104	388	12	190	1,324	9,639	13.7%
2013	416	30	281	74	504	48	356	1,708	9,501	18.0%
2014	433	37	255	85	578	68	532	1,989	9,406	21.1%
2015	422	53	230	107	613	92	681	2,199	9,389	23.4%
2016	473	38	260	89	657	122	827	2,466	9,284	26.6%

Source: Utility Renewable Portfolio Standard Status Report.
* Customer-sited PV.

Table 5.4 shows the shares of renewable electricity net generation by source based on the RPS data. From 2005 to 2016, the share of biomass decreased from 56% to 19%; the share of biofuels increased from 0% to 2%; the share of geothermal decreased from 31% to 11%; the share of hydro decreased from 12% to 4%; the share of wind increased from 1% to 27%, the share of solar (excluding customer-sited solar) increased from 0% to 5%; and the share of customer-sited solar increased from 0% to 34%.

Table 5.4 Share of Total Renewable Electricity Net Generation in Hawaii

	Share of Renewable Electricity Net Generation (%)							
Year	Biomass	Biofuels	Geothermal	Hydro	Wind	Solar	Solar Cus*	Total
2005	56%	0%	31%	12%	1%	0%	0%	100%
2006	54%	0%	25%	11%	9%	0%	0%	100%
2007	41%	0%	24%	8%	26%	0%	1%	100%
2008	42%	0%	24%	8%	24%	0%	1%	100%
2009	41%	1%	17%	11%	26%	0%	3%	100%
2010	38%	0%	21%	7%	28%	0%	6%	100%
2011	31%	5%	20%	8%	29%	0%	8%	100%
2012	26%	2%	20%	8%	29%	1%	14%	100%
2013	24%	2%	16%	4%	29%	3%	21%	100%
2014	22%	2%	13%	4%	29%	3%	27%	100%
2015	19%	2%	10%	5%	28%	4%	31%	100%
2016	19%	2%	11%	4%	27%	5%	34%	100%

Source: HECO and KIUC Renewable Portfolio Standard Status Report.
* Customer-sited PV.

The share of renewable electricity based on the RPS data is significantly above the share of renewable electricity calculated using the EIA data. There are several reasons for the difference.

First, the EIA data does not include electricity generated by the consumer-sited PV systems but the RPS data include electricity generated by the customer-sited PV systems.

Second, the EIA share of renewable electricity is based on net generation and the RPS share of renewable electricity is based on electricity sold by the utilities. The net generation or net electricity to system includes electricity sold by the utilities and electricity lost. For the utilities, electricity lost accounted for about 4.7% of net electricity to system (utility gross generation – utility station use + purchased electricity). As shown in Table 5.5, the EIA electricity net generation data is about 5.3% above the EIA electricity sold and about 7.2% above the RPS electricity sold data in 2016. For electricity sold, the EIA data were higher than the RPS data from 2014 to 2016.

Third, the renewable electricity data from EIA are inconsistent with the data from the RPS. In 2016, total renewable electricity from EIA was 1,760 GWH, while total renewable electricity from RPS was only 1,639 GWH.

Table 5.5 Comparison of Data from EIA and Utility RPS

	Electricity in GWHs			EIA Sold	EIA Net Gen. Above	
	EIA	RPS	EIA Net	Above	EIA	RPS
Year	Sold	Sold	Generation	RPS Sold	Sold	Sold
2005	10,539	10,539	11,523	0.0%	9.3%	9.3%
2006	10,568	10,568	11,559	0.0%	9.4%	9.4%
2007	10,585	10,585	11,533	0.0%	9.0%	9.0%
2008	10,390	10,390	11,376	0.0%	9.5%	9.5%
2009	10,126	10,126	11,011	0.0%	8.7%	8.7%
2010	10,017	10,013	10,836	0.0%	8.2%	8.2%
2011	9,962	9,962	10,723	0.0%	7.6%	7.6%
2012	9,639	9,639	10,469	0.0%	8.6%	8.6%
2013	9,503	9,501	10,267	0.0%	8.0%	8.1%
2014	9,475	9,406	10,204	0.7%	7.7%	8.5%
2015	9,511	9,389	10,120	1.3%	6.4%	7.8%
2016	9,445	9,284	9,949	1.7%	5.3%	7.2%

Source: EIA and Utility RPS.
NA: not available.

The share of renewable electricity calculated using the EIA data only measures the share of the electricity industry. The share of renewable electricity using the RPS data; however, is not an accurate measure of the share of renewable electricity. The RPS electricity sold does not include customer-sited solar consumed directly by consumers (without sold to the utilities), but the total renewable electricity net generation includes the generation of customer-sited solar systems. The customer-sited PV was included in the numerator but excluded in the denominator. In addition, electricity sold by the utilities does not include electricity lost, while utility net to system includes electricity lost.

A more accurate measure should be total net renewable electricity generation over total net generation of the electric power industry (utility net to system) plus customer-sited solar (the Alternative methodology). The utility net to system include utility net generation (utility gross generation minus utility station use) plus purchased electricity (or gross generation by IPP and CHP producers minus their station use). As shown in Table 5.6, based on the Alternative methodology and the RPS data, the share of renewable electricity in 2016 was 23.3%, lower than the share from the RPS report (26.6%), but higher than the share calculated using the EIA data (17.7%).

Table 5.6 Comparison of the Share of Renewable Electricity Calculated

Year	Renewable Net Generation GWh A	Utility Net to System GWh B	Customer Sited PV GWh C	Total Net Generation GWh D=B+C	% of Renewable Electricity		
					Alternative* E=A/D	RPS	EIA
2005	716	11,122	2	11,125	6.4%	6.8%	6.8%
2006	865	11,181	4	11,185	7.7%	8.2%	7.9%
2007	945	11,195	8	11,203	8.4%	8.9%	8.6%
2008	976	10,985	12	10,998	8.9%	9.4%	9.0%
2009	963	10,672	33	10,705	9.0%	9.5%	10.9%
2010	950	10,569	53	10,622	8.9%	9.5%	10.9%
2011	1,186	10,485	90	10,575	11.2%	11.9%	12.5%
2012	1,324	10,147	190	10,336	12.8%	13.7%	13.4%
2013	1,708	9,999	356	10,355	16.5%	18.0%	15.6%
2014	1,989	9,884	532	10,416	19.1%	21.1%	16.7%
2015	2,199	9,884	681	10,566	20.8%	23.4%	16.9%
2016	2,466	9,747	827	10,574	23.3%	26.6%	17.7%
2017	2,526	9,599	914	10,513	24.0%	27.6%	NA

Source: EIA and Utility RPS and MFR.

* Calculation methodology: Renewable Net Generation/Total Net Generation (A/D)