Holding Visitors Accountable: The Impact of Tourism on Global Climate Change

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Abstract: Visitors are attracted to Hawai‘i's unparalleled beauty and fragile ecosystem, yet impose significant environmental impacts both locally and globally. Greenhouse gas (GHG) emissions can be mitigated through visitor taxes, energy policy, and industrial measures. This model provides greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide) generated by residents, government, and five types of visitors in an applied general equilibrium model of Hawai‘i's economy. The extensive Hawai‘i dataset includes consumer and industry data for 131 sectors, ten agents, and six fossil fuel types. Simulation results are presented for macroeconomic and per capita indicators including visitor and household expenditures, price indices, income distribution, output, and gross state product. The model simulates various visitor expenditures scenarios including a million dollar increase in visitor spending. The model provides a framework to incorporate economic and environmental impacts of visitor industry growth on a small open economy.

Key words: Climate change, greenhouse gas, sustainable tourism
JEL Classifications: Q01, D58, Q25, Q40, Q54, R13

1. Introduction

Early work on tourism and climate change focused on how changing climate could lead to changing tourist destinations. Current research has shifted in focus to looking at tourism's impact on climate change (Dubois & Ceron 2006, 401). There is a complicated negative interaction between tourism activities and climate change and thus it is important to estimate tourists' role in creating greenhouse gas emissions to determine both regional and global mitigation strategies.

Islands are particularly interesting areas of study because they are both particularly vulnerable to climate change and often heavily economically reliant on tourism. In addition, because islands are generally natural resource scarce, tourism activities put additional strains on the natural ecosystem. This study focuses on the island State of Hawai`i to provide a better understanding of the effects of visitor-specific activities on infrastructure and natural resource demand, as well as greenhouse gas emissions.

Visitor economic activity is traced through Hawai`i's economy using a Computable General Equilibrium (CGE) model. Hawai`i is an ideal island example for modeling because it is truly a small open economy and because an incredible level of data detail is maintained by the State for the tourism sector. As such, both direct and indirect visitor expenditures are traced through the economy based on visitor types by location (ex: from Japan, Canada, U.S.-West and U.S.-East). From the baseline calibration of the model, a million dollar increase in nominal visitor expenditures is simulated to show changing sector-level economic activity, infrastructure demand and greenhouse gas emissions.

The main findings of the study are that: 1) Although residents have an overall larger emissions impact than do tourists, it is tourists that have a higher per person/day impact. 2) Areas of particular difference between resident and tourist behavior are in air transportation, hotel accommodations, real estate, and larger infrastructure demand such as waste/sewer, water, electricity, and natural gas consumption. 3) Visitor activity often depends on visitor origin and thus different visitor-types have different economic and environmental impacts. Typically high-spending tourists do not necessarily have higher-economic impacts due to spending on goods that are largely imported to Hawai`i (ex: retail). In addition, different visitor types are associated with different emissions impacts because of differing transportation activities like rental cars versus tour buses.

2. Background & Motivation

Hawai`i and Climate Change

Although Hawai`i is not necessarily a large greenhouse gas emitter, making up only 0.3% of total U.S. greenhouse gas emissions in 1990,[1] as an island, Hawai`i is a canary in the coal mine for global climate change. Islands are particularly susceptible to the effects of global warming because of rising sea levels, increased frequency and voracity of tropical

[1] The most recent DBEDT *Inventory of Hawaii Greenhouse Gas Emissions* is for 1990. Although now quite dated, DBEDT's 1990 figures give the most comprehensive order-of-magnitude estimate of current greenhouse gas emissions available.

storms, the effects on already limited water resources, and stresses on fragile land and ocean ecosystems. The island of Tuvalu, for instance, because of its small and flat nature, has already experienced tremendous environmental damage from sea level rise and unusual tides. About a quarter of Tuvalu's population has left for New Zealand, making them amongst the world's first "environmental" refugees.[2] A 1995 publication from the U.S. Federal Environmental Protection Agency (EPA) states that the temperature in Honolulu has increased by 4.4 degrees Fahrenheit over the last century and precipitation has decreased by 20%. Sea level rose in test points in Honolulu, Nawiliwili and Hilo by 6 to 14 inches and the EPA estimates another 17-25 inches by 2100. The EPA also estimates the cumulative cost of sand replenishment from a 20 inch sea level rise to be \$340 million to \$6 billion. Mitigating anthropogenic greenhouse gases is clearly potentially both economically and environmentally beneficial.

From a political perspective, it behooves Hawai`i not to be a free-rider in global greenhouse gas pollution. Doing Hawai`i's part in mitigating greenhouse gases means being able to say to the continent and world, "we've done our part, please do yours." The policy environment in Hawai`i is beginning to adopt this mentality. For instance, twin greenhouse gas bills requiring Hawai`i to meet Kyoto Protocol emissions levels are being reviewed in the 2007 Hawai`i State Legislative session.[3]

While the legislation in question describes well the *why* Hawai`i should reduce greenhouse gas emissions, it leaves open the *how*. Although the majority of greenhouse gas emissions in Hawai`i are resident driven, because tourism is Hawai`i's largest private sector industry, the resident base is inherently tied to tourism activities. Understanding tourisms impact on economic and environmental indicators has policy implications not only for tourism sectors but for the economy at large.

Tourism and Climate Change

Typical models of tourism demand focus mainly on tourism destination choice and seldom consider climate change as a factor (see Crouch, 1995; Morley, 1998; Witt and Witt, 1995). As climate change issues becomes more important with increasing physical science and prediction capabilities, many researchers have attempted to analyze the complex relationship between climate change and tourism. The World Tourism Organization (WTO) acknowledged in 2003 the two-way relationship between tourism and climate change.

On the one hand, climate change will impact many tourist destinations and tourism related sectors through changes in weather patterns, ocean temperatures and other ecosystem-tourism linkages (see Smith et al 2001; Scott et al 2004; Hamilton et al 2005). Maddison (2001), Lise and Tol (2002) and Hamilton (2003) estimate the changes in demand of British, Dutch and German tourists, respectively, because of changing climate in tourist destinations.

[2] Time and Tide (2005).
[3] House Bills 678 and 226.

On the other hand, tourism is a major contributor to climate change because tourism related activities are inherently fossil fuel dependent: air travel, rental cars, bus tours, and other sightseeing transportation. Tourists additionally consume energy indirectly by staying in hotels, eating at restaurants, and even playing golf. While the literature on the impact of climate change on tourism is quite extensive, the literature on tourism's impact on climate change is less so, probably because of the complexity of the problem and the difficulty in collecting tourism related data.

Modeling Approaches

The GTAP-E dataset and subsequent modeling efforts have set the standard for emissions and climate change modeling at a national level. The many applications of GTAP-E in regards to climate change policies are widespread – from analyzing the Kyoto Protocol and emissions trading schemes, carbon taxes, and more closely related climate models like Richard Tol's FUND model (for example, see Bohringer 1999 & 2000, Berrittella et al 2006, and Tol 2005). The question of tourism's impact on climate change through greenhouse gas emissions, particularly for a region below the national level like the island State of Hawai`i requires a more regional approach to modeling and data development.

Becken et al (2006) use a top-down and bottom-up approach to measure national carbon dioxide emissions from tourism in New Zealand, enriching the standard system of national accounts and Input-Output table with emissions data. The advantage of this approach is that it includes energy demand or emissions specifically resulting from tourism in the comprehensive national statistics, which adds an environmental component to the input-output table. Though this approach creates a rich dataset linking Input-Output data to environmental amenities, it nonetheless lacks the inter-sector, inter-regional linkage effects and price mechanisms of CGE.

This paper takes a similar data-gathering approach to Becken et al (2006), but in a CGE framework. This analysis uniquely uses CGE as a method of linking tourism activities and alternative tourism scenarios to greenhouse gas emissions to get detailed price feedback effects. In addition, the model groups tourists by place of origin.

3. Data & Methodology

To assess the effects of the alternative tourism growth scenarios, a numerical applied general equilibrium model of Hawai`i is developed. A Social Accounting Matrix is assembled that describes the flow of goods, services, and factors through each economy in a baseline year. For each production sector, the purchases of intermediate inputs and primary factors (labor and capital) are provided. Demand in each sector is a combination of intermediate demand and final expenditures by households, government, exporters, and investors. The baseline conditions are derived from a 1997 Input-Output table for the State of Hawai`i comprised of 131 industrial sectors, three factor markets, and 11 agents of final demand. Summary data are given in Tables 1 and 2. Table 3 provides an overview of initial, or baseline, infrastructure usage by sector. To give the model a dynamic nature as well as enrich specific data elements, the Social Accounting Matrix is supplemented with additional data on visitor expenditures, population, and greenhouse gas emissions for petroleum use.

3.1. Output and Production

In terms of total state output ($58.7 billion), the largest sectors include real estate (15.4%), services (25.8%), government (14.6%), trade (10.4%), construction (6%), hotels (5.9%), and manufacturing (5.8%). Interestingly enough, agriculture and entertainment comprise similar shares of the economy, each amounting to about 1.4% of total output. Key infrastructure sectors, represented by other transportation (2.6%) and utilities (2.9%), which includes waste remediation services and waste/sewer, are also important to the economy. In terms of the wage bill (compensation of employees), 27.2% is in services, with the next largest sector being trade (11.1%). Notably, government amounts to almost one-third (33.2%) of the total wage bill in the state. Proprietor's income ($2.1 billion) is about one-tenth the volume of the compensation of employees ($21.6 billion). Services account for nearly half (48.9%) of total proprietor's income. Other value added including depreciation of capital accounts generates income of $14.9 billion with real estate accounting for a disproportionate share (41.0 %) of demand. The job count reflects the state's heavy reliance on services, trade, and government, which together comprise 66.7% of the total job count.

Table 1. Structure of Output and Production in Hawai`i

Industry	Output	Inter-industry demand	Imports	Comp. of employees	Proprietor income	Other value added	Jobs
Total	$58.7 bil	$14.4 bil	$5.7 bil	$21.6 bil	$2.1 bil	$14.9 bil	742,231
Agriculture	1.4%	1.9%	1.4%	1.3%	1.8%	1.0%	2.9%
Construction	6.0%	7.9%	11.1%	5.8%	11.6%	1.7%	4.5%
Manufacturing	5.8%	5.9%	28.8%	2.4%	2.2%	2.4%	2.4%
Air Transportation	3.5%	4.8%	5.3%	2.4%	0.3%	3.5%	1.4%
Other Transport.	2.6%	4.5%	4.0%	1.7%	1.2%	1.8%	1.9%
Entertainment	1.4%	1.8%	1.8%	1.4%	3.0%	0.8%	2.7%
Golf	0.4%	0.6%	0.3%	0.4%	0.0%	0.2%	0.5%
Hotels	5.9%	7.6%	3.4%	5.9%	1.7%	5.7%	5.6%
Real estate	15.4%	13.7%	2.9%	1.8%	17.6%	41.0%	3.9%
Restaurants	3.9%	5.5%	5.2%	3.7%	2.0%	2.3%	6.8%
Trade	10.4%	9.9%	8.2%	11.1%	9.6%	10.9%	14.9%
Other Services	25.8%	30.3%	23.4%	27.2%	48.9%	17.3%	29.8%
Utilities	2.9%	4.1%	2.5%	1.6%	0.1%	4.1%	0.8%
Government	14.6%	1.5%	1.4%	33.2%	0.0%	7.3%	22.0%

Source: *The Hawai`i Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawai`i, March 2002 (updated August 2003).

3.2. Consumer Expenditures

Table 2 provides a glimpse at final demand, allowing the comparison between household and visitor purchases in the economy. Not surprisingly, household purchases are dominated by expenditures on services ($7.8 billion), real estate ($5.2 billion), and trade ($3.0 billion). Visitor spending, on the other hand, is dominated by expenditures on hotels and condominium rentals ($3.2 billion), air travel ($1.6 billion), and restaurant meals ($1.1 billion). Comparing total purchases, households spend approximately $25 billion annually, compared to $10.9 billion annually by visitors. Note too that while households spend $595 million on utilities, the visitor purchases of utilities are indirect, through the consumption of other goods and services.

Table 2. Household and Visitor Expenditures in Hawai`i

	Household Expenditures		Visitor Expenditures	
Industry	**($ million)**	**(%)**	**($ million)**	**(%)**
Total	$24,962.0	100.0%	$10,931.0	100.0%
Agriculture	122.0	0.5%	18.4	0.2%
Construction	0.0	0.0%	0.0	0.0%
Manufacturing	683.0	2.7%	296.2	2.7%
Air Transportation	337.9	1.4%	1,555.2	14.2%
Other Transport.	406.3	1.6%	536.3	4.9%
Entertainment	207.3	0.8%	569.4	5.2%
Golf	88.5	0.4%	141.3	1.3%
Hotels	170.0	0.7%	3,247.4	29.7%
Real estate	5,211.4	20.9%	239.7	2.2%
Restaurants	1,017.1	4.1%	1,126.2	10.3%
Trade	2,998.3	12.0%	1,278.0	11.7%
Other Services	7,832.2	31.4%	439.8	4.0%
Utilities	595.3	2.4%	0.0	0.0%
Government	264.9	1.1%	45.6	0.4%
Imports	5,027.8	20.1%	1,437.6	13.2%

Source: *The Hawai`i Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawai`i, March 2002 (updated August 2003).

3.3. Petroleum Products Demand

Data on petroleum products distribution include highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane. The data shows the sales of petroleum products by industry refiners and distributors to some broad categories.

Table 3 shows the sales of petroleum products by industry refiners and distributors to some broad categories.

Table 3. Sales of Petroleum Products by Refiners and Distributors in Hawai`i, 1997 gallons

		Total
Gasoline	Civilian Service Stations	321,784,596
	Military Service Stations	22,528,170
	Vehicle Fleets	3,199,812
	Agriculture	377,622
	Commercial	1,920,492
	Construction	250,068
	Government	4,782,708
	Industrial	152,124
	Marine	41,874
	Sold to Jobbers	24,104,934
	Sold to Other Fuel Distributors	15,017,772
	Adjustment	8,281,182
Diesel Fuel Oil	Electricity Generation - IPP	11,796,456
	Electricity Generation - Plantation	1,451,268
	Electricity Generation - Utility	94,631,643
	Federal - Military	1,486,002
	Federal - Other	2,100
	State Government	494,508
	County Government	5,673,360
	Vessel Bunkering Intra-State	9,895,116
	Vessel Bunkering Overseas, Bonded	49,397,292
	Vessel Bunkering Overseas, Non-Bond	64,722
	Other	58,754,572
	Own Use	95,760
Highway Diesel	Local Highway	2,034,690
	Transit Diesel	3,746,232
	Tourbus Diesel	250,824
	Trucks Diesel	13,253,646
	Buses Diesel	9,201,570
Residual Fuel Oil	Construction	243,810
	Electricity Generation - IPP	87,714,690
	Electricity Generation - Plantation	9,634,884
	Electricity Generation - Utility	357,275,853
	Federal - Military	2,291,184
	Vessel Bunkering Intra-State	5,491,164
	Vessel Bunkering Overseas, Bonded	55,892,046
	Vessel Bunkering Overseas, Non-Bond	20,255,592
Aviation Gasoline	Aviation Intra-State	1,346,352
Jet Fuel Kerosene	Aviation Intra-State	135,363,858
	Aviation Overseas, Bonded Fuel	373,867,536
	Aviation Overseas, Non-Bonded Fuel	218,681,484
	Federal - Military	31,352,664
	State Government	5,376
	Sold to Jobbers	43,134
Propane - NonUtility	Industrial/Commerical	24,898,136
	Residential	4,849,733
Propane - Utility		37,043,058
Grand Total		2,030,921,669

Source: DBEDT, the Energy, Resources, and Technology Division.

Table 4 shows the petroleum products consumption by industry and final demand sectors in the State of Hawai`i in 1997.

Table 4. Petroleum Product Demand, 1997

Industry	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total Petroleum Products
Crops	-	746,942	2,604,574	-	-	3,933	3,355,449
Animal	-	111,382	388,388	-	-	8,560	508,331
Commercial fishing	-	41,874	9,895,116	-	-	-	9,936,990
Landscaping services	72,340	-	-	-	-	-	72,340
Construction and mining	4,546,298	-	15,863,262	-	243,810	672,683	21,326,053
Food processing	1,042,704	-	744,575	-	6,195,250	515,130	8,497,659
Clothing manufacturing	192,643	-	-	-	-	-	192,643
Chemical manufacturing	201,564	-	-	-	-	54,157	255,721
Petroleum manufacturing	105,005	-	11,227,779	-	1,719,896	-	13,052,681
Other manufacturing	892,897	-	-	-	-	219,939	1,112,837
Air transportation	-	-	-	341,297,863	-	170,075	341,467,938
Trucking	3,892,064	-	-	-	-	113,922	4,005,986
Water transportation	-	-	-	-	5,491,164	164,407	5,655,571
Ground transportation	4,159,761	-	-	-	-	-	4,159,761
Automobile rental	5,368,765	-	-	-	-	-	5,368,765
Parking lots	253,367	-	-	-	-	-	253,367
Transit	3,746,232	-	-	-	-	-	3,746,232
Performing arts	59,036	-	-	-	-	-	59,036
Amusement	216,423	-	-	-	-	-	216,423
Recreation	197,921	-	-	-	-	419,251	617,172
Museums historical	101,146	-	-	-	-	-	101,146
Sightseeing transport	10,900,986	-	-	-	-	137,984	11,038,970
Golf courses	303,438	-	-	-	-	-	303,438
Hotels	2,666,304	-	9,429,435	-	-	8,160,672	20,256,411
Real estate	2,956,766	-	-	-	-	3,528,412	6,485,178
Restaurants	1,856,887	-	6,566,916	-	-	6,751,132	15,174,935
Wholesale trade	6,110,586	-	-	-	-	-	6,110,586
Retail trade	6,763,502	-	-	-	-	138,825	6,902,328
Information	834,344	-	2,950,674	-	-	-	3,785,018
Finance business professional	3,252,622	-	8,199,000	-	-	-	11,451,622
Travel reservations	579,005	-	2,047,663	-	-	-	2,626,668
Education private	406,520	-	1,437,666	-	-	-	1,844,186
Health services	3,160,288	-	8,457,242	-	-	1,426,350	13,043,881
Laundry	228,969	-	809,752	-	-	784,575	1,823,295
Other services	2,290,256	-	-	12,084,299	-	74,289	14,448,844
Electricity	-	-	96,002,773	-	446,710,281	-	542,713,054
Natural gas	-	-	-	-	-	37,043,058	37,043,058

Table 4. Petroleum Product Demand, 1997 (continued)

Waste management private	2,093,012	-	-	-	-	1,553,838	3,646,850
Water sewer	2,199,573	-	-	-	-	-	2,199,573
Other government	1,745,502	-	961,106	-	-	-	2,706,608
Total industry demand	**73,396,725**	**900,199**	**177,585,921**	**353,382,162**	**460,360,401**	**61,941,194**	**1,127,566,601**
Residents demand	322,678,447				-	4,849,733	327,528,180
Visitors demand	21,634,319				-	-	21,634,319
Change in inventories	8,281,182				-	-	8,281,182
State and local gov't demand	4,037,444		5,206,762	5,376	-	-	9,249,583
Federal gov't demand	-		1,488,102	31,352,664	2,291,184	-	35,131,950
Exports	-		49,462,014	375,920,202	76,147,638	-	501,529,854
Total demand in Hawai`i	**430,028,117**	**900,199**	**233,742,799**	**760,660,404**	**538,799,223**	**66,790,927**	**2,030,921,669**

3.3.2. Emissions from Petroleum Products Use

The methodology of estimating the greenhouse gas emissions is based on the EPA State Workbook (1995). Formulas for calculating the emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) are applied to the petroleum products consumption in the State of Hawai`i in 1997. See Appendix I for more detail on emissions methodology. Table 5 shows emissions for carbon dioxide, methane and nitrous oxide from petroleum products use in the base year.

Table 5. Hawai`i Emissions from Petroleum Products Use, 1997 (tons)

Industry	Carbon Dioxide (CO2)	Methane (CH4)	Nitrous Oxide (N2O)
Crops	24,348	3.06	0.64
Animal	3,683	0.46	0.13
Commercial fishing	110,003	0.03	1.38
Landscaping services	731	0.02	0.01
Construction and mining	229,038	11.36	3.86
Food processing	101,934	1.09	2.61
Clothing manufacturing	1,945	0.06	0.03
Chemical manufacturing	2,390	0.06	0.29
Petroleum manufacturing	147,339	11.16	0.01
Other manufacturing	10,458	0.28	1.18
Air transportation	3,636,808	111.39	0.97
Trucking	40,050	1.13	1.11
Water transportation	71,793	0.02	1.61
Ground transportation	44,538	2.43	0.95
Automobile rental	54,144	1.50	0.77
Parking lots	2,555	0.07	0.04
Transit	41,493	2.86	1.04
Performing arts	595	0.02	0.01
Amusement	2,183	0.06	0.03

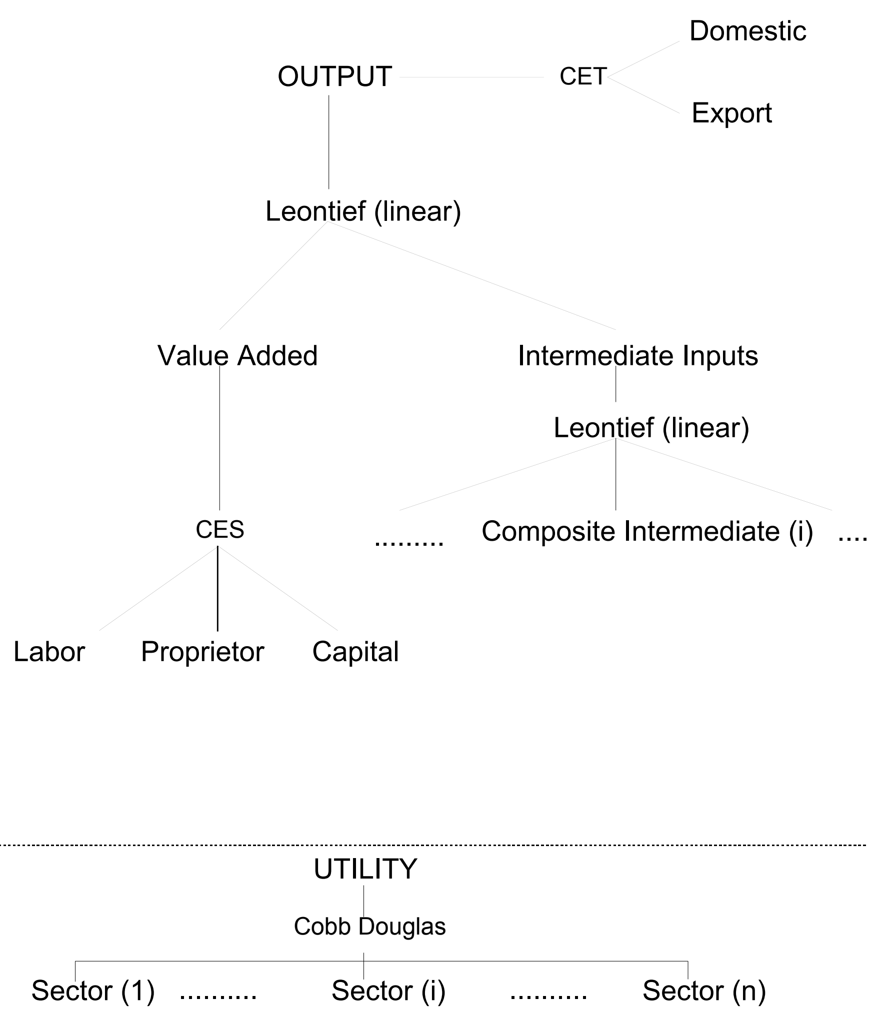
Table 5. Hawai`i Emissions from Petroleum Products Use, 1997 (tons) (continued)

Recreation	4,743	0.11	2.03
Museums historical	1,020	0.03	0.01
Sightseeing transport	117,619	6.37	3.14
Golf courses	3,060	0.08	0.04
Hotels	184,797	7.61	39.35
Real estate	52,937	1.25	17.27
Restaurants	135,694	5.42	32.50
Wholesale trade	61,625	1.71	0.88
Retail trade	69,119	1.91	1.63
Information	41,095	2.08	0.12
Finance business professional	123,613	6.03	0.47
Travel reservations	28,519	1.44	0.08
Education private	20,023	1.01	0.06
Health services	134,888	6.33	7.26
Laundry	16,418	0.66	3.78
Other services	152,313	4.59	0.69
Electricity	6,806,709	189.18	11.89
Natural gas	242,705	4.42	176.88
Waste management private	31,289	0.77	7.72
Water sewer	21,371	0.22	0.21
Other government	27,604	0.77	0.16
Total industry	12,803,190	389.06	322.85
Residents	3,166,854	32.77	52.96
Visitors	210,195	2.16	2.03
Change in inventories	80,458	0.83	0.78
State and local gov't	96,953	3.66	0.38
Federal gov't	380,163	10.24	0.34
Exports	5,535,242	111.65	18.26
Total emissions in Hawai`i	22,273,055	550.37	397.60

4. Model

Hawai`i is modeled as a small and very open economy, in which visitor expenditures generate a significant share of foreign exchange. Visitors demand a bundle of goods, such as hotel and restaurant services, most of which are not importable. Goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Final demand is generated by households, visitors, various government entities, and exports. Within this context, prices are calibrated to clear markets.

Figure 1. Diagram of Production and Utility Functions



4.1. STEAM: Consumer behavior

There are two types of consumers in the economy, residents (r) and visitors (v). The economy produces n commodities and imports a composite good m. The Cobb-Douglas utility function for the type-h consumer is given by

$$U_h = \prod_i C_{hi}^{b_{hi}} \qquad \sum_i b_{hi} = 1 \tag{4.1}$$

where C_{hi} is consumption and b_{hi} the income expenditure share of i= 1,..,n,m by consumer $h = r,v$. An import matrix has not been constructed for Hawai`i and information on imports by commodity is not available at this time. We thus assume that consumer h consumes imports C_{hm} in fixed proportion to income b_{hm}, as is consistent with Cobb-Douglas preferences.

A single representative resident maximizes utility (U_r) subject to the following budget constraint

$$\sum_i p_i C_{ri} = p_L L + P_R R + P_K K + \overline{p}_{fx} BP - T_r \tag{4.2}$$

where prices p_i represent the market prices for imports and commodities i = 1,..n, m respectively. The resident derives income from factors of production including labor (L), proprietor income (R), and capital (K), where p_L, p_R, p_K are the market price of the respective factors. The resident pays a lump-sum tax (T_r) to the state and local government. The resident also receives foreign exchange ($\overline{p}_{fx} B$) from a balance of payment deficit, described below in equation (12).

A representative visitor with exogenous income (I_v) maximizes utility (U_v) subject to the budget constraint

$$\sum_i p_i C_{vi} = I_v (1 + \gamma_V) \tag{4.3}$$

where γ_V serves as an exogenous visitor expenditure shock parameter.

4.2. STEAM: Production and sales of goods and services

Final output (Y_j) in sector j = 1,.., n is produced according to a nested production function comprised of intermediate inputs (Z_{ij}) of commodity i, composite imports (M_j), and value added (V_j) as shown in Figure 1. The first level is a Leontief production function

$$Y_j = \min[Z_{1j} / \alpha_{1j}, ...Z_{nj} / \alpha_{nj}, M_j / \alpha_{mj}, V_j / \alpha_{vj}] \tag{4.4}$$

where a_{ij}, a_{mj}, a_{vj} are unit input coefficients for intermediates, imports, and value added respectively.

A sub-production function describes the substitutability between labor (L_j), capital (K_j), and proprietor income (R_j) in producing real value added (V_j) in each sector j, where σ_j is the constant elasticity of substitution (CES) among value added variables.

$$V_j = [\alpha_{Lj} L_j^{(\sigma_j - 1)/\sigma_j} + \alpha_{Kj} K_j^{(\sigma_j - 1)/\sigma_j} + \alpha_{Rj} R_j^{(\sigma_j - 1)/\sigma_j}]^{\sigma_j/(\sigma_j - 1)} \tag{4.5}$$

Commodity Y_j is differentiated for sale on domestic and international markets, as given by a constant elasticity of transformation (CET) function between domestic (D_j) sales and exports (X_j).

$$Y_j = [\beta_{Dj} D_j^{(\varepsilon_j - 1)/\varepsilon_j} + \beta_{Xj} X_j^{(\varepsilon_j - 1)/\varepsilon_j}]^{\varepsilon_j/(\varepsilon_j - 1)} \tag{4.6}$$

In this function, ε_j is the elasticity of transformation and β_{Dj}, β_{Xj} are parameter shares.

4.3. STEAM: Government revenue and expenditures

Three government agencies procure goods and services in the economy: the state and local government (denoted *SL*), the federal military government (denoted *FM*), and the federal civilian government (denoted *FC*). Each government type purchases fixed levels of domestic commodities ($\overline{G}_{gi}$) and imports ($\overline{G}_{gm}$) to assure a constant level of public provision is maintained, where $g = SL, FM, FC$.

The state and local government depends entirely on the economy for the tax base.

$$\sum_i p_i \overline{G}_{SLi} = \sum_i p_i Y_i \tau_i + T_r \tag{4.7}$$

A primary source of revenue is the State's goods and services tax ($\square_i$) on the sales (Y_i) of commodity i. The state and local government also impose a variety of taxes, such as property and income taxes, on residents. In this model, this resident tax (T_r) adjusts endogenously to maintain constant government expenditures and a balanced budget.

The budgets of the federal government agencies are assumed to be completely independent of state economic conditions. In the case of Hawai`i, this is a reasonable characterization. Owing to Hawai`i's unique strategic assets, such as Pearl Harbor, federal military expenditures are determined largely by international political conditions. As a relatively small state, federal civilian expenditures are not well-correlated with federal taxes paid by Hawai`i residents. In the model, federal inflows are assumed to adjust endogenously to assure that federal government objectives are maintained. Thus, the federal public sector budget constraints are given by the following equations

$$\begin{aligned} \sum_i p_i \overline{G}_{FMi} &= I_{FM} \\ \sum_i p_i \overline{G}_{FCi} &= I_{FC} \end{aligned} \tag{4.8}$$

where the sum on the left-hand side represents the cost of public expenditures and I_{FM}, I_{FC} represents endogenous federal revenue inflows for military and civilian agencies, respectively.

3.4. STEAM: Market clearing conditions

Constant returns to scale and perfect competition ensure that the producer price (p_j) equals the marginal cost of output in each sector *j*. In addition, the State and Local Government collects a general excise tax (□$_j$) on sales. This in turn implies that the value of total output equals producer costs, where p_L, p_K, p_R, equal the market price of labor, capital, and proprietor income respectively.

$$p_j Y_j (1+\tau_j) = \sum_{l=1,..,n} p_l Z_{lj} + P_L L_j + p_k K_j + p_R R_j + p_m M_{Yj} \tag{4.9}$$

The model accommodates alternative labor force assumptions characterized by the following market clearing condition.

$$\overline{L}_0 \ (1 + \gamma_L) = \sum_j L_j. \tag{4.10}$$

The labor force grows at a rate, γ_L, which is related to exogenous demographic factors forecasted using an ARIMA model.

Other factors of production are assumed to be fully mobile across sectors, but fixed in total supply, with endowments of $\overline{K}$, $\overline{R}$. Given the competitive nature of the model, all factors will be fully employed in equilibrium. The parameter γ_L gives the rate at which the labor supply increases. The following market clearing conditions hold in the factors markets

$$\overline{K} = \sum_j K_j, \quad \overline{R} = \sum_j R_j \tag{4.11}$$

Sector *j* output, which supplied to the domestic market (D_j), is demanded by consumers $h \in \{r,v\}$, government agencies $g \in \{SL,FC,FM\}$, and industries $j = 1,..,n$.

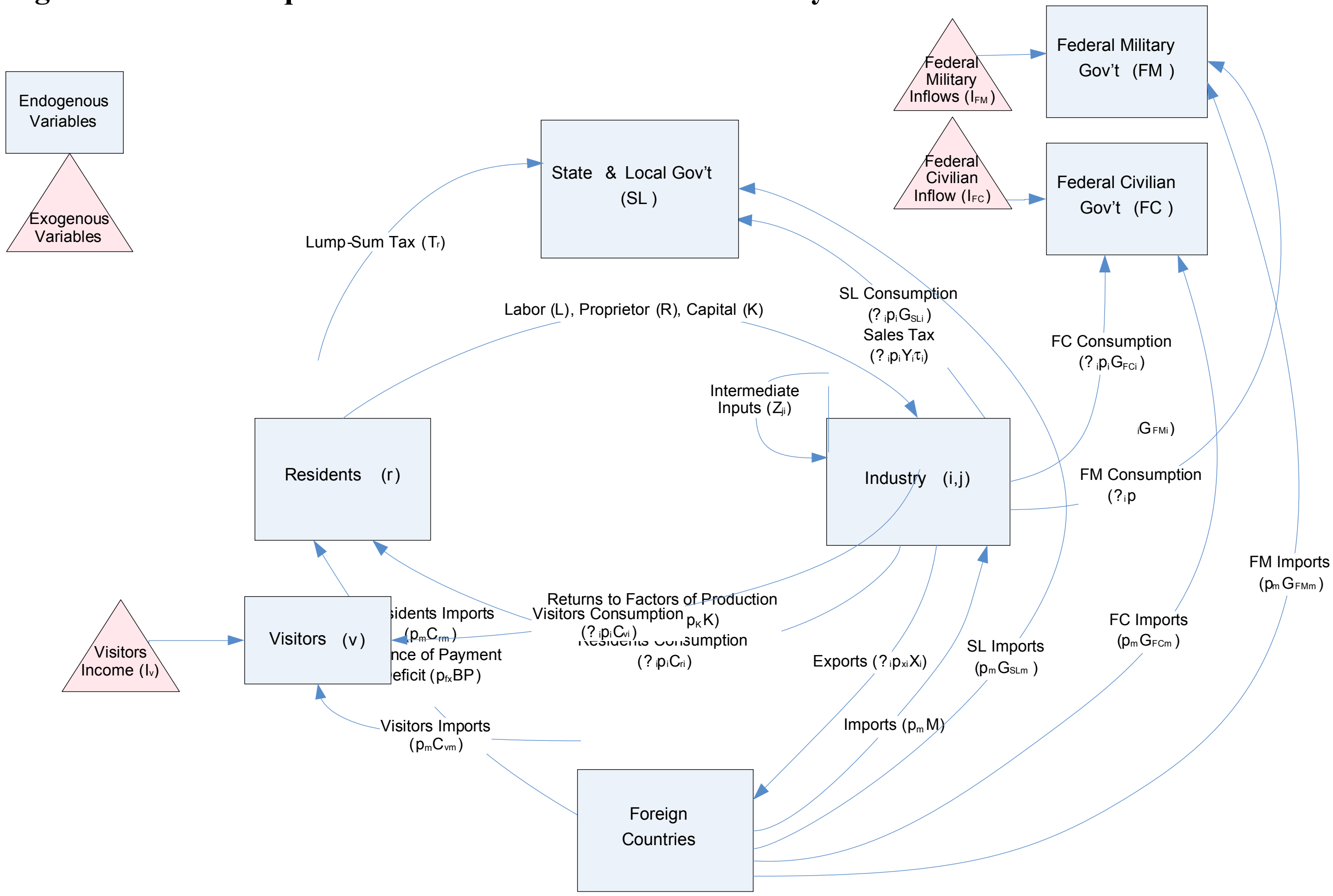
$$D_j = \sum_h C_{hj} + \sum_g G_{gj} + \sum_l Z_{li} \tag{4.12}$$

A balance of external payments (*BP*) is maintained under the assumption of a fixed (dollar) exchange rate ($\overline{p}_{fx}$), where $\overline{p}_{fx}$ is the price of foreign exchange, the exchange rate. The quantity of imports (*M*) are thus constrained by the inflow of dollars obtained from visitor expenditures (I_v), federal government expenditures (I_{FM}, I_{FC}), Hawai`i exports (X_j), and visitor expenditures. It is assumed that the economy is a small price taker on world markets and thus import and export prices are perfectly inelastic.

$$\overline{p}_{fx} BP = \overline{p}_m M - I_v - I_{FM} - I_{FC} - \sum_j \overline{p}_{xj} X_j \tag{4.13}$$

A schematic representation of the system is given in Figure 2. The computable general equilibrium model thus represents a classic Walrasian system. Given the convexity of the production and expenditure sets, there exists a unique vector of equilibrium prices at which markets clear (supply is equal to demand). Changes in parameters of the system induce an optimal response on the part of producers and consumers resulting in a new vector of market-clearing equilibrium prices. The model is estimated numerically using the GAMS (General Algebraic Modeling Systems) – MPSGE platform.

Figure 2. General Equilibrium Model of Hawai`i's Economy



5. Baseline Results

Baseline Petroleum Demand

Table 6 shows direct and indirect petroleum demand for residents and visitors. Residents and visitors consume highway gasoline and diesel directly for automobile transportation. Residents consume propane directly. All other petroleum types, non-highway gasoline and diesel, jet fuel, and residual fuel oil, are consumed indirectly by both residents and visitors through activities like air transportation and electricity consumption. Residents consume nearly double the physical amount of petroleum products than visitors.

Residents consume significantly more of each type of petroleum product, with the exception of jet fuel in which visitors consume nearly four times more than residents.

Table 6. Petroleum Demand (Gallons)

	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total
Direct Use by Residents	322,678,447	-	-	-	-	4,849,733	327,528,180
Direct Use by Visitors	21,634,319	-	-	-	-	-	21,634,319
Indirect Use by Residents	28,243,395	352,068	86,292,940	72,386,075	257,424,341	26,364,681	471,063,500
Indirect Use by Visitors	29,102,211	129,881	41,041,050	267,185,513	85,017,315	22,845,142	445,321,112
Total Residents	**350,921,842**	**352,068**	**86,292,940**	**72,386,075**	**257,424,341**	**31,214,414**	**798,591,679**
Total Visitors	**50,736,530**	**129,881**	**41,041,050**	**267,185,513**	**85,017,315**	**22,845,142**	**466,955,432**

Table 7 shows demand on a per resident and per visitor day basis. It is important to note that while residents consume overall more petroleum products, visitors consume petroleum products more intensely. The average visitor consumes over four times more petroleum per day than the average resident.

Table 7. Petroleum Demand per Day (Gallons)

	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total
Direct Use per Resident	0.73	-	-	-	-	0.01	0.74
Direct Use per Visitor	0.38	-	-	-	-	-	0.38
Indirect per Resident	0.06	0.001	0.20	0.16	0.58	0.06	1.07
Indirect per Visitor	0.51	0.002	0.72	4.66	1.48	0.40	7.76
Total per Resident Day	**0.79**	**0.001**	**0.20**	**0.16**	**0.58**	**0.07**	**1.81**
Total per Visitor Day	**0.88**	**0.002**	**0.72**	**4.66**	**1.48**	**0.40**	**8.14**

Table 8 and 9 converts petroleum consumption into tons of carbon dioxide emissions overall and on a per person day basis. While the dataset created includes other types of anthropocentric greenhouse gases, carbon dioxide is by far the largest greenhouse gas offender and thus the analysis will concentrate on carbon dioxide specifically. Logically, the pattern of carbon dioxide emissions follows that of petroleum product demand.

Table 8. Carbon Dioxide Emissions (Tons)

	Highway Gasoline & Diesel	Non-highway Gasoline	Non-hwy Diesel	Jet Fuel, Aviation Gasoline	Residual Fuel Oil	Pro-pane	Total
Direct Emissions by Residents	3,135,079	-	-	-	-	31,775	3,166,854
Direct Emissions by Visitors	210,195	-	-	-	-	-	210,195
Indirect Emissions by Residents	286,394	3,421	950,535	771,097	3,309,779	172,741	5,493,966
Indirect Emissions by Visitors	301,462	1,262	452,665	2,846,208	1,093,075	149,681	4,844,353
Total Emissions by Residents	**3,421,473**	**3,421**	**950,535**	**771,097**	**3,309,779**	**204,516**	**8,660,820**
Total Emissions by Visitors	**511,657**	**1,262**	**452,665**	**2,846,208**	**1,093,075**	**149,681**	**5,054,548**

Table 9. Carbon Dioxide Emissions per Day (Tons)

	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total
Direct Emissions per Resident	0.0071	-	-	-	-	0.0001	0.0072
Direct Emissions per Visitor	0.0037	-	-	-	-	-	0.0037
Indirect Emissions per Resident	0.0006	0.0000	0.0021	0.0017	0.0075	0.0004	0.0124
Indirect Emissions per Visitor	0.0053	0.0000	0.0079	0.0496	0.0191	0.0026	0.0844
Total Emissions per Resident Day	**0.0077**	**0.0000**	**0.0021**	**0.0017**	**0.0075**	**0.0005**	**0.0196**
Total Emissions per Visitor Day	**0.0089**	**0.0000**	**0.0079**	**0.0496**	**0.0191**	**0.0026**	**0.0881**

Simulation Results

The following simulation looks at the impact of a million dollar increase in nominal visitor expenditures. Gross State Product increases by nearly half a million dollars and average household income increases by $248. There is also an increase in inflation by 0.3%.

Table 10. Difference in Macroeconomic Indicators

Household Expenditures	$147,574
Gross State Product	$447,086
Average Household Income	$248
Visitor Spending	$672,081
Paasche Inflation Index	0.3%

An increase in visitor expenditures means a subsequent increase in sector-level output, where tourism-related industries experience growth and other industries decline (for example, the value of agricultural output declines). See Table 11 for a summary of changes in sector-level output and consumer expenditures.

Table 11. Sector-Level Output, Resident and Visitor Expenditure Shifts (Nominal)

	Direct Visitor Spending	Household Spending	Output
Agriculture	$ 1,005	$ 721	$ (81,483)
Manufacturing	$ 23,828	$ 12,902	$ (108,633)
Air Transportation	$ 142,278	$ 17,947	$ 162,947
Other Transport	$ 49,066	$ 21,577	$ 74,753
Entertainment	$ 52,090	$ 11,008	$ 63,042
Golf	$ 12,924	$ 4,702	$ 17,626
Hotel	$ 297,087	$ 9,026	$ 307,658
Real Estate	$ 21,925	$ 276,766	$ 425,380
Restaurants	$ 103,026	$ 54,014	$ 161,202
Trade	$ 116,913	$ 159,232	$ 322,337
Services	$ 36,342	$ 282,659	$ 321,764
Utilities	$ -	$ 24,241	$ 68,885
Government	$ 4,170	$ 14,069	$ 352,413
Total	$ 860,655	$ 888,864	$ 2,087,889

Increases in total industry output and increased resident wealth as a result of increased visitor spending leads to increases in energy demand – in electricity, utility gas, and petroleum. Table 12 shows the physical increase in energy demand as a result of the visitor simulation.

Table 12. Energy Demand Impacts

Electricity (Watts)	**128,266,362**
Utility gas (Btu)	**106,933,699**
Petroleum (Gallons)	**70,683**

Table 13 shows changes in petroleum demand by sector, linking to changes in carbon dioxide emissions. It is interesting to note that decreases in output in non-tourism related sectors like agriculture lead to a decrease in petroleum demand and carbon dioxide emissions in agriculture.

Table 13. Petroleum Demand and Carbon Dioxide Impacts

	Petroleum (gallons)	Carbon Dioxide (CO2)
Agriculture	**-1,489.5**	**-13.8**
Manufacturing	-578.9	-6.8
Air Transportation	**17,151.9**	**182.7**
Transportation	**1,063.2**	**11.2**
Entertainment	40.4	0.3
Golf	12.4	0.1
Hotel	**1,054.0**	**9.6**
Real Estate Rental	48.6	0.4
Restaurants	549.9	4.9
Trade	176.1	1.8
Services	-335.3	-3.9
Electricity	**8,208.5**	**103.0**
Utility Gas	643.3	4.2
Government	26.9	0.2
Resident	**14,970.9**	**144.8**
Visitor	**29,652.1**	**288.1**
Total	**71,196.4**	**726.8**

Million Dollar Shock by Visitor Type

In addition to overall visitor expenditures, the State of Hawai`i Department of Business, Economic Development and Tourism maintains detailed data on visitor expenditures by place of origin (U.S.-West, U.S.-East, Japan, Canada, and other International).[4] Table 14 shows how a visitor-type spends an additional million dollars. It is interesting to note that the Japan-tourist would spend more on manufactured goods, entertainment, and traded goods (i.e. retail & other imports).

Table 14. How Visitors Spend $1 Million

	US-WEST	US-EAST	Japan	Canada	Other Int'l
Agriculture	$2,332	$1,515	$1,943	**$2,399**	$1,725
Manufacturing	$25,892	$22,801	**$58,576**	$25,055	$29,301
Air Transportation	$152,088	**$215,464**	$90,434	$144,853	$181,013
Other Transport	**$60,214**	$49,370	$45,615	$53,608	$85,640
Entertainment	$51,573	$49,116	**$72,558**	$49,269	$105,236
Golf	**$17,695**	$16,449	$8,421	$15,911	$10,926
Hotel	$355,813	$323,307	$327,481	**$482,122**	$341,588
Real Estate	$26,402	$24,047	$24,385	**$33,602**	$24,192
Restaurants	**$129,302**	$119,393	$120,806	$81,362	$81,954
Trade	$121,816	$125,913	**$205,652**	$68,769	$97,166

[4] The data is largely collected through survey information when visitors enter the State.

Other Services	**$51,472**	$47,590	$38,760	$40,276	$38,431
Government	**$5,290**	$4,926	$5,048	$2,664	$2,686
Imports	$111	$108	**$320**	$109	$142
Total	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000

Table 15 shows the increase in petroleum demand and carbon dioxide by visitor type as a result of a million dollar increase in expenditures.

Table 15. Petroleum Demand and Carbon Dioxide Impacts by Visitor Type

	US-West	US-East	Japan	Canada	Other Intl	Average
Gallons Petroleum	44,391.0	53,024.4	108,776.3	**118,101.5**	128,120.8	71,196.4
Carbon Dioxide (CO_2)	466.0	557.9	1,079.6	**1,183.2**	1,284.0	726.8

6. Conclusions

A 2005 Hawai`i Tourism Authority survey said that 59% of Hawai`i residents believe that the islands are being run for tourists at the expense of visitors. This is a very strong statement and, while it ties into a variety of regional policy questions, it also begs the question of who should consume vital resources and whether visitors should continue to pollute the atmosphere through greenhouse gas emissions at no charge.

This study creates a framework by which to account for visitor activity and visitor-types with subsequent links to greenhouse gas emissions. This study finds that although residents have an overall larger emissions impact than do tourists, it is tourists that have a higher per person/day impact. Areas of particular difference between resident and tourist behavior are in air transportation, hotel accommodations, real estate, and larger infrastructure demand such as waste/sewer, water, electricity, and natural gas consumption. Visitor activity often depends on visitor origin and thus different visitor-types have different economic and environmental impacts. Typically high-spending tourists do not necessarily have higher-economic impacts due to spending on goods that are largely imported to Hawai`i (ex: retail). In addition, different visitor types are associated with different emissions impacts because of differing transportation activities like rental cars versus tour buses.

While the breakdown of visitors into types is crucial in targeting policy, future work includes linking tourists by activity types (ex: business, ecotourism, campers, etc.) rather than from place of origin. Such a designation would lead to more concrete information regarding visitor behavior and greenhouse gas emissions.

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Appendix I. Linking Petroleum Product Use and Carbon Dioxide Emissions

For CO2 emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor of each petroleum product (Table I-1) (e.g. 42.8 for highway gasoline and 44 for highway diesel), and then divided by 2000 to provide the amount of carbon emission in tons. Finally, the amount of carbon emission in tons is converted to CO2 by multiplying an oxidation factor of 0.99 and by 44 tons CO2/12 tons of C to yield tons of CO2 emitted. The each petroleum product, the calculation of its CO2 emission is:

$$CO2_{PP} = PP * (CO_2\,Emission\ Factor/2000) * 0.99 * (44/12), \qquad (3.1)$$

where

subscript PP = emission from petroleum products, including highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane,
PP = petroleum products in millions of Btu, including highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane.

For CH4 emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor (e.g. 0.0016 for highway gasoline and 0.011 for highway diesel), and then divided by 2000 to provide the amount of CH4 in tons. The each petroleum product, the calculation of its CH4 emission is:

$$CH4_{PP} = PP * (CH_4\,Emission\ Factor/2000). \qquad (3.2)$$

For N2O emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor (e.g. 0.0015 for highway gasoline and 0.004 for highway diesel), and then divided by 2000 to provide the amount of N2O in tons. The each petroleum product, the calculation of its N2O emission is:

$$N2O_{PP} = PP * (N_2O\ Emission\ Factor/2000). \quad (3.3)$$

Table 6 shows the emissions from petroleum products use by industry and final demand sectors in Hawai`i in 1997.

Table I-1. Emission Factor for Petroleum Product Use

Petroleum Products	Carbon Dioxide (CO2)	Methane (CH4)	Nitrous Oxide (N2O)
Highway and Non-highway Gasoline	42.8	0.0016	0.0015
Highway Diesel	44	0.011	0.004
Non-highway Gasoline, Marine	42.8	0.011	0.0044
Non-highway Diesel, Agriculture Vehicle	37.8	0.024	0.0044
Non-highway Diesel, Commercial, Industrial, and Military	44	0.009	N/A
Non-highway Diesel, Marine	44	N/A	0.002
Non-highway Diesel, OFS	44	0.0007	N/A
Non-highway Diesel, CT	44	0.0124	N/A
Non-highway Diesel, IC	44	0.009	0.004
Jet Fuel	43.5	0.0044	N/A
Aviation Gasoline	41.6	0.133	0.002
Residual Fuel Oil, Marine	47.4	N/A	0.002
Residual Fuel Oil, Military	47.4	N/A	0.002
Residual Fuel Oil, Construction, Commercial, and Industrial	47	0.0022	N/A
Residual Fuel Oil, OFS	47.4	0.0015	N/A
Residual Fuel Oil, CT	47	0.0124	N/A
Propane, Residential	37.8	0.0021	0.098
Propane, Commercial/Industrial	37.8	0.0025	0.1

Source: EPA State Workbook (1995)