Material Flows on the Island of Hawai‘i

Meleah Houseknecht
Choony Kim
Austin Whitman

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1 Introduction and Objectives

In the domain of industrial ecology there is a substantial body of literature about the practice of industrial ecology in the context of islands. Using an island as a unit of analysis is valuable both to the researcher and to those interested in the sustainability of the island itself. The researcher benefits from the island's clear boundaries (most often defined by a surrounding water body) and a relative advantage in data collection provided by the fact that borders are monitored. Material flows are therefore relatively easier to understand on islands than in larger, more complex non-island systems. Stakeholders in the island's sustainability stand to benefit because island systems often face acute resource limitations not found in larger systems or subsystems. As Deschenes and Chertow note, many unique problems arise where the closed, fragile island environment is coupled with open, global economic systems.[1]

The Center for Industrial Ecology at Yale has carried out extensive work on several islands, most notably Puerto Rico, where researchers have worked over the past seven years on building a comprehensive map of industrial activity on the island. The success of this research led the Center to undertake research on the Big Island of Hawai'i, hereafter referred to as "the Big Island," in the spring of 2006. The analysis had two components: a Material Flow Analysis (MFA), and an Energy Systems Analysis (ESA). This report covers the work done by the MFA research group.

The primary objective of this research was to build a big-picture map of material flows on the Big Island. Other objectives included:

- Identifying current and future vulnerabilities in the material flow path
- Quantifying the island's sustainability challenges
- Identifying opportunities for industrial symbiosis[2]

The intended audience of this research includes state and local policymakers, NGOs and other stakeholder groups, investors, business managers, and any others who have a primary interest—either professionally, financially, or personally—in sustainability on the Big Island.

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[1] P. J. Deschenes and Marian Chertow, "An Island Approach to Industrial Ecology: Towards Sustainability in the Island Context," Journal of Planning and Management, Vol. 47, No. 2, 201–217, March 2004.

[2] For a clear discussion of the concept of industrial symbiosis, see J. Ehrenfeld and M. Chertow, "Industrial symbiosis: The legacy of Kalundborg," in *A Handbook of Industrial Ecology*, R.U. Ayres and L.W. Ayres, Eds., Edward Elgar, Cheltenham, UK, 2002.

2 Methodology

The authors of this report, master's degree candidates at Yale University's School of Forestry and Environmental Studies, derived the information from both primary and secondary sources. A majority of the primary research took place during March 2006 on a trip to the Big Island funded by the Kohala Center, a local non-government organization based in Kamuela (a.k.a. Waimea), HI, and by Yale's Center for Industrial Ecology. On-island research consisted of interviews of government officials, politicians, business leaders, employees of non-profits, consultants, and island residents. A complete interview list can be found in Appendix A.

While primary research provided much of the background for making qualitative insights about material flows on the Big Island, much of the quantitative data used in the report comes from published reports, all of which are footnoted in the report. The single most significant source of data was the report "Waterborne Commerce of the United States," hereafter referred to as "the USACE report," which contains data collected by the United States Army Corps of Engineers on incoming and outgoing freight at the island's two main harbors, Kawaihae and Hilo. Where possible, the data in this report were treated as a "top-down" reference point, and were cross-referenced with industry-specific data on material flows that was gleaned from alternate sources and used to identify a "bottom-up" reference point. An example of this method is as follows:

Top-down analysis

Petroleum products import data from the USACE report:

Naptha	52.2 Gg
Distillate Fuel Oil	78.41 Gg
Residual Fuel Oil	117.85 Gg
Total	248.46 Gg

Bottom-up analysis

Data from Hawaii Electric Light Co (HELCO) and Yale energy systems research:

Electricity generation $10{,}393 \times 10^9$ BTUs

Estimated conversion factor: 44.09×10^9 BTUs/Gg fuel

Calculated fuel requirements: 10,393/44.09 = 235.7 Gg

As this example shows, if we know the amount of electricity produced on the island from fossil fuels, and have a rough conversion factor, [3] we can calculate the amount of fuel needed. By checking this number with the number on the USACE report, we can tell whether the numbers are consistent with each other. In this way we are able to zero in on defensible estimates for materials uses in a range of industries and settings.

3 Demographic and Political Context

As its name suggests, the Big Island occupies 62 percent of the total land area of the Hawaiian Islands, or 10,500 square kilometers, but is home to only 13 percent of the state's population, or roughly 165,000 permanent residents. With a population density of roughly 16 people per square kilometer, the Big Island is the least densely populated of the major islands (compared to 41, 63, and 567 residents per square kilometer for Kaua'i, Maui, and O'ahu respectively.)[4] Despite its low population density, the Big Island is experiencing rapid growth: between 1984 and 2004 the Island's resident population grew 36 percent (15 percent in the last decade).[5] Even as it expands, the island's population retains its historical racial and ethnic diversity, with 55 percent of residents identifying as White, 47 percent identifying as Asian, and 30 percent identifying as Native Hawaiian (the total is over 100 percent due to the fact that many Hawaiians identify as more than one race).[6]

The island comprises a single political unit—the County of Hawai'i—governed by a nine member county council. It is also made up of nine districts, designated separately from the county council election districts, which are shown in Appendix B. It is generally considered to be split into two important political units: the west side, centered in the town of Kailua-Kona, and the east side, centered in the town of Hilo. The Hawai'i County Council and county government staff are primarily located on the east side in Hilo, which is the traditional seat of power for the county, as it is the second largest city in the state of Hawai'i. A great deal of the growth in population is on the west side of the island, which has a reputation among "east-siders" for being home to many recent immigrants to the island, particularly wealthy second home-owners from California.[7] This demographic split sets the stage for ongoing political tensions between the east and west sides of the island.

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[3] Conversion from data found at http://msucares.com/pubs/infosheets/is1621.html.

[4] *County of Hawaii Data Book*, 2004 "Table 1.3-- LAND AREA AND POPULATION DENSITY, STATE OF HAWAII, BY COUNTIES AND ISLANDS: 2000." (Original source: U.S. Census Bureau). Available at http://www.hawaii-county.com/databook_current/dbooktoc.htm (20 March 2006).

[5] ibid, "Table 1.1-- RESIDENT POPULATION, STATE OF HAWAII, BY COUNTIES: 1980, 1983 TO 2004." (Original source: U.S. Census Bureau).

[6] ibid, "TABLE 1.16c-- POPULATION SHARE BY RACE BY COUNTY: APRIL 1, 2000 and JULY 1, 2004." (Original source: Hawaii State Department of Business, Economic Development and Tourism).

[7] Nelson Ho, Deputy Director, Hawai'i County Department of Environmental Management, personal communication 7 March 2006, and other anecdotal comments.

4 Economic Context

In order to understand material flows on the Big Island it is helpful to look first at financial measures of activity on the island. In dollar terms, the Big Island's economy, once dominated by the sugarcane industry, is now largely centered on services, as is evident both in employment figures and the breakdown of the county's tax base (see Appendix C). The three largest areas of economic activity, retailing, services, and contracting, contribute 60 percent of the island's tax base, while manufacturing and producing (agriculture and mining) together make up less than 3 percent. In addition to providing initial insights, economic activity data are useful for identifying trends on the island.

Yet from the standpoint of a material flow analysis, the economic numbers are merely a starting point. Where money is being spent is not always where materials are flowing, where constraints exist, or where opportunities lie (for example, in an economy that is highly focused on service industries there may be significant spending associated with labor and other non-material products). Our analysis focuses on identifying the areas where *material flows* are most significant. The lack of manufacturing and heavy industry on the island and the economic dominance of non-industrial sectors suggest that the most compelling material flows stories on the Big Island of Hawai'i may be slightly obscured.

5 Material Flows

Figure 1 shows the aggregate material flows on the island. It is divided into two primary categories: materials inputs on the left side and the fate of those inputs on the right side. All units are in gigagrams.

As can be seen in the figure, Hawai'i Island is highly import dependent—76 percent of its inputs are imported from off of the island. Of this 76 percent, a majority of materials imported (by mass) are for construction. Of the 24 percent of inputs that are extracted on the island a majority of these, 60 percent, are also for construction activities.

The Figure 1 excludes water supplied by the County and water diverted for agricultural uses, as well as wastewater effluent. This is because, by mass, water use dwarfs all other material flows and would visually obscure the other data if included. Data on water use and wastewater are included in sections 5.7 and 5.8 respectively.

The sources of the data and assumptions used to construct Figure 1 are given in Appendix D.

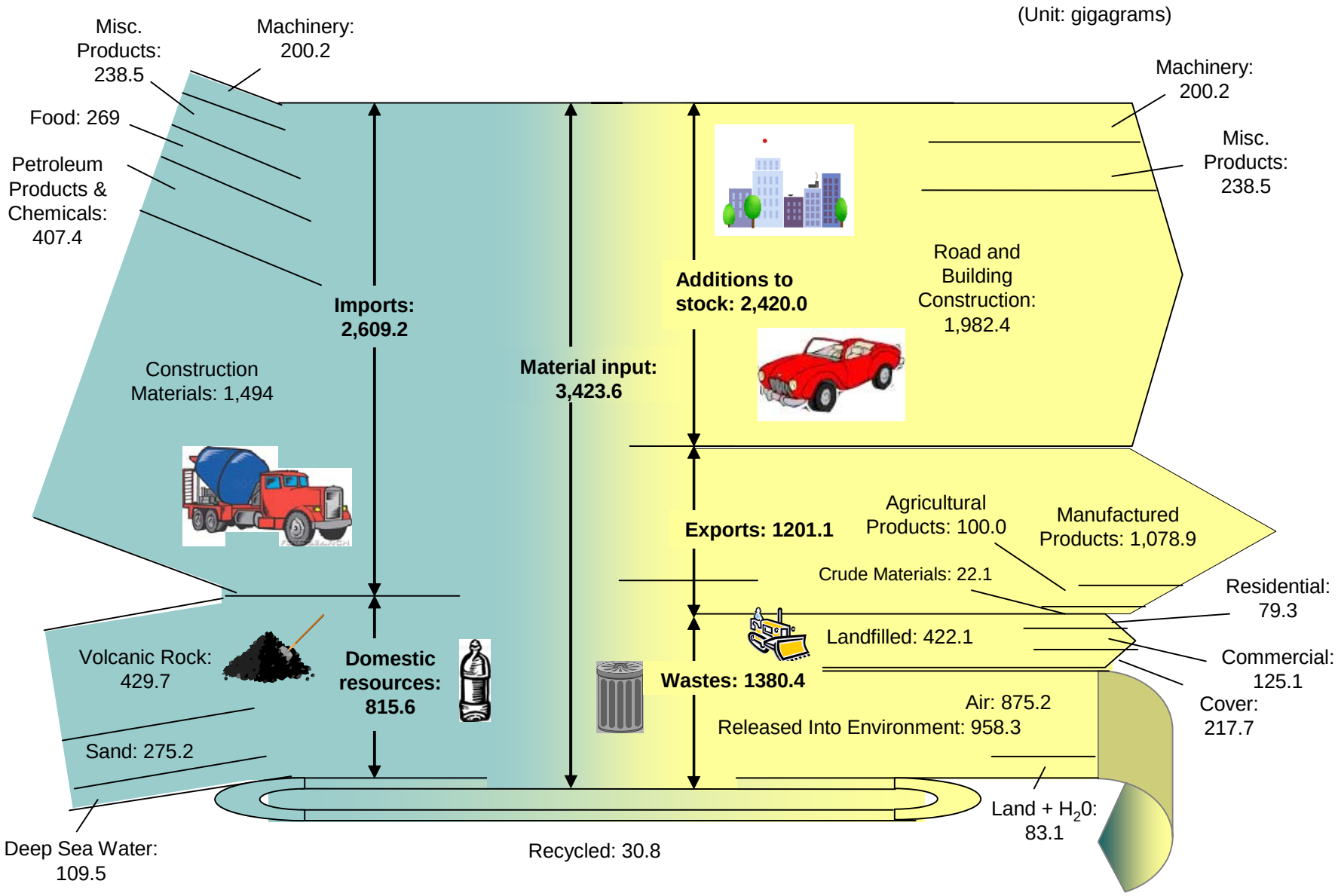

Figure 1: Material Flow Diagram for the Big Island of Hawai'i.

5.1 Agriculture

Agriculture on the Big Island was once an economic mainstay that centered on the sugar cane industry. By the early 1990s, cheaper substitutes from South America and the Philippines, coupled with rising costs of transport to mainland markets, had virtually wiped out the sugar cane industry, leaving an aging agricultural infrastructure and a portion of the population unemployed.

Since that time agriculture on the Big Island has been making a transition toward a greater diversity of crops, but the realities of cheap foreign production, quarantine restrictions on produce shipped to the mainland U.S., and continued high export costs remain a hindrance to the industry and limit its growth potential.

The irony is that the Big Island's climate is conducive to growing many types of crops, and could theoretically support the island's entire demand for fresh produce, but it remains cheaper to *import* goods from other markets. The result is that the bulk of the Big Island's food supply is brought in by cargo vessel.

Estimates of the annual agricultural production (2005) on the Big Island are shown at right. Local production of food is driven by sufficient local demand (e.g. eggs), sufficiently high global market prices (e.g. ginger and papaya), or the unique growing conditions of the Big Island (e.g. macadamia nuts).

Table 1: Annual Production, 2002

Crop	Gg
Papaya	27.2
Macadamia Nuts	25.6
Beef cattle	6.9
Bananas	5.9
Veggies	4.9
Eggs	1.1
Guava	3.2
Ginger	2.2
Coffee	0.9
Aquaculture	0.5
Honey	0.5
Taro	0.2
Avocados	0.2
Pork	0.0
Wool	0.0
Pineapples	0.0
Cut flowers	unknown
Foliage Crops	unknown
Total	79.3

With the exception of eggs and a small amount of fresh produce, most of the agricultural production on the island is exported. These estimates of quantity, arrived at through bottom-up estimation based on interviews with a representative from the Big Island farm bureau and people in several important agricultural sectors, correspond roughly with the data on the USACE report. It is worth noting that there is significant overlap between the island's imports and exports. Nearly all of the beef *consumed* on the island, for example, is imported, while nearly all of the beef *produced* on the island is exported.

Principal material inputs to the agricultural industry include water, fuel, and fertilizer. Farms in the northwestern part of the island draw on the Hamakua ditch system, separate from municipal water supply, which is a vestige from the days of sugar-growing and delivers 69.3 million liters of water per day to farmers in the Hamakua district (see Appendix B) and in Waimea. The Farms in the Kona district draw on well systems, and those in Puna and the wet eastern side of the island draw on rainfall. With demand on the ditch system currently at less than 40 percent of the erstwhile demand from sugar plantations, and plentiful rainfall across much of the island, access to water does not fall high on the list of threats to Big Island agriculture.

High costs of fuel and farm equipment, together with high labor costs, are among the reasons that Big Island agriculture has trouble competing on the world market. Since it is very difficult to estimate use-hours for farm equipment, we assume that the diesel fuel and lubricants for farm equipment appear in the USACE report. According to a 2002 USDA census and the Big Island Farm Bureau, over 60 percent of the roughly 2,100 motorized farm vehicles on the island are small tractors (engines less than 40 h.p.),[8] and most agricultural products are harvested by hand,[9] suggesting that farm equipment does not represent a significant material stock, and that fuel use is not currently a significant material flow associated with agricultural activity.

Because of the already high input costs for agriculture and the abundance of fungi, bugs, and other pests, organic farming practices are not found widely on the Big Island. Fertilizers (28.2 Gg/year) and pesticides (1 Gg/year) are important inputs to the industry. Both of these inputs are considered to be released to the environment after use.

Cattle

One of the largest calf-raising and cattle operations in the U.S. is located on the Big Island. Parker Ranch was founded in 1847 and owns close to 71,000 hectares on the island. The operation raises beef cattle from birth until they reach a weight of 180 kg, at which point they are shipped off of the island to be raised to harvestable weight. Until 1991 the ranch raised its beef on the island from birth to slaughter, but rising costs of feed made it more profitable to send the cattle off of the island. Four barges leave the island each year, two in spring and two in fall, and Parker Ranch beef eventually makes it to the shelves of Whole Foods and Safeway as premium grass-fed beef.

The livestock operations of Parker Ranch do not require significant material inputs. Sunlight, water, and the fuel needed to run ranch vehicles are the primary inputs, with the major outputs being the cattle themselves. We estimate that Parker Ranch's cattle production, at 11,000 head per year, represents about one-third of total Big Island cattle production, and calculate 6.9 Gg of cattle exported each year, which accounts for the bulk of the "Animal Products" exports listed in the USACE report.

Macadamia Nuts

By weight, macadamia nuts constitute the second most significant agricultural product grown on the Big Island. To understand this industry we visited the Mauna Loa macadamia nut farm outside of Hilo. With a total annual processed nut production of roughly 3.4 Gg, Mauna Loa's operations account for just over 50 percent of the nuts processed on the island.

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[8] U.S. Department of Agriculture, "2002 Census of Agriculture: Hawaii," AC-02-A-11, June 2002, p. 229.

[9] Lorie Farrell, Big Island Farm Bureau, personal communication, 8 March 2006.

Figure 2: Material flow diagram for the Mauna Loa macadamia nut processing plant.

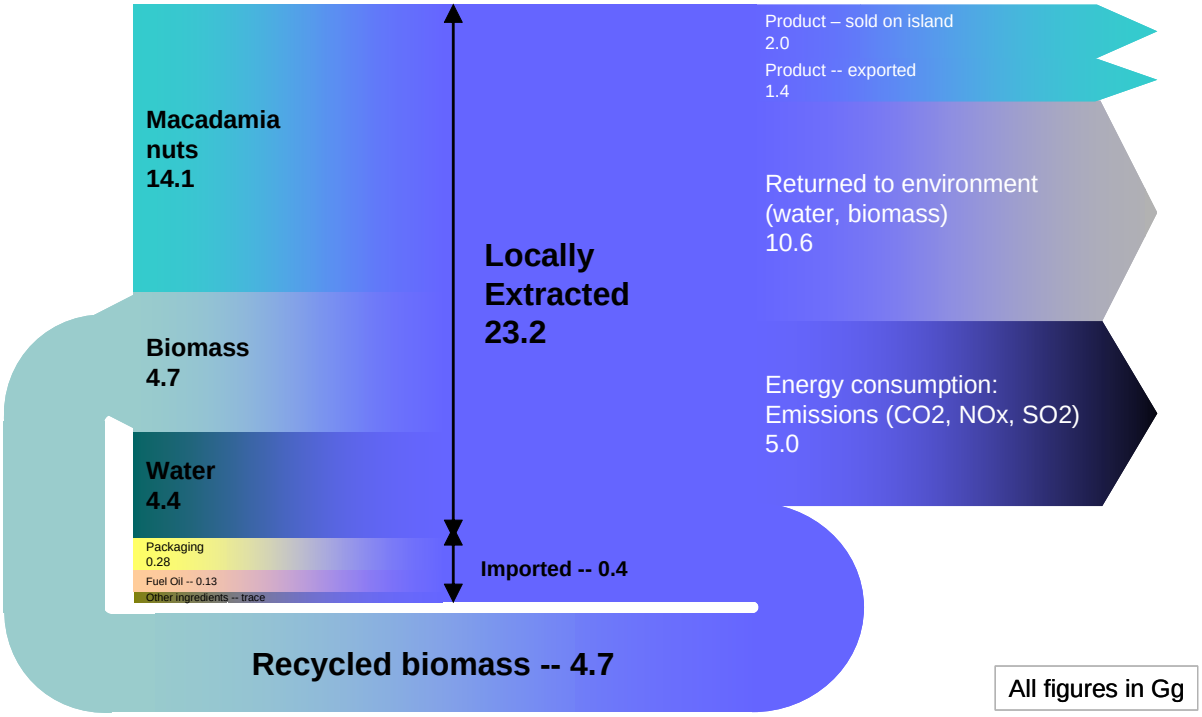

Figure 2 shows a site-specific material flow analysis of the Mauna Loa processing plant. From a materials standpoint the plant exhibits an impressive import/export ratio, relying on imports to the island for only a small portion of its total production requirements. Water is extracted locally from two deep wells on the property, and macadamia nuts are grown primarily in orchards adjacent to the processing plant, minimizing the need to transport raw materials around the island.

One of the most interesting features of the facility from an industrial ecologist's viewpoint is that the plant derives 60 percent of its power from an on-site generator that burns the discarded shells of macadamia nuts, and another 20 percent from discarded fuel oil. EPA emissions checks on the generators ensure that emissions are in compliance with air quality standards.

5.2 The Construction Industry

Due in part to the island's rapid growth (particularly on the west side), the construction industry is responsible for the largest set of material flows on the island (see Figure 1). Estimating use of construction materials is difficult because there are no centralized records kept. Some materials are imported as raw materials, others as manufactured products, and still others are combined with materials (almost solely rock, sand and water) extracted on the island.

Major inputs to the construction industry include concrete, steel, brick, wood, glass, and other metals (such as copper for pipes), as well as water for concrete production and fossil fuels used to power heavy equipment. The most reliable numbers available for construction material use on the island are from the USACE report. Since very few materials are manufactured on the island, the amounts of most building products used can be assumed to be approximately the same as those imported. The limited timber production on the island is almost solely for export, so quantities of timber for use in construction can also be taken from import numbers.

Table 2: Imported Construction Materials

Product Category	Gg	Percentage of Total
Fabricated metal products	1314.5	88.0%
Cement & concrete	76.4	5.1%
Lumber	64.2	4.3%
Misc. mineral products	25.8	1.7%
Iron & steel bars & shapes	4.3	0.3%
Primary wood products	2.7	0.2%
Iron & Steel pipe & tube	2.1	0.1%
Pigments & paints	1.5	0.1%
Non-metal minerals	1.0	0.1%
Glass & glass products	1.0	0.1%
Sand & gravel	0.6	0.0%

Concrete, asphalt, and other materials that contain rock and sand are the only construction materials that incorporate a significant quantity of locally extracted resources. Concrete manufacture on the island begins with 76.4 Gg of imported cement, which is brought in from Asia via Honolulu by Hawai'i Cement, the island's only importer. It is then distributed to the island's six concrete producers, three of which are located in Kona, two in Hilo, and one in Kea'au. There are seven quarries on the island (all on the west side) where various types of rock are extracted. The quarries consist primarily of hard rock pits, cinder pits, and sand deposits. Rock is often extracted, crushed, and used on-site, rather than transported, with many of the island's contractors owning their own crushers. Jason Macy of West Hawaii Concrete estimates about 7,250 Gg (8 million tons) of annual extraction on the island, including rock used in concrete manufacturing and also rock which is simply moved from one part of a construction site to another in the process of leveling. A much more conservative estimate of 213.2 Gg is used in Figure 1, which only includes rock used for concrete and county road building activities. This assumes a 2.4 to 1 ratio of rock to cement used in concrete (as communicated by Jason Macy), and that all cement entering the island is mixed into concrete. The concrete manufacturing process also includes the local extraction of 275.2 Gg of sand and the emission of large amounts of waste water. (Macy estimates that West Hawaii Concrete alone consumes 7.6 Gg—2 million gallons—of water per month.)

There is currently very little known about the volume and fate of construction and demolition waste on the island. Legal disposal takes place at the island's two landfills, but it not tracked as a separate waste stream by the county (it is generally lumped in with all "commercial waste" in county records). Jason Macy estimates that as much as 90 percent of this waste goes into "a hole

on the property" or is illegally dumped due to the high tipping fees that must be paid for legal disposal. There is very little recycling of construction and demolition waste on the island. This is largely due to the fact that cement is still more expensive to recycle on the island than to make new; the only incentive, therefore, is the cost savings from eliminating disposal fees. Macy also blames low recycling rates on state regulations that prevent the use of recycled concrete in new or renovated state buildings.[10]

5.3 The Visitor Industry

The visitor industry on the island is significant, with an estimated 1 in 10 people on the island having "de facto" (non-resident or visitor) status.[11] Based on known hotel occupancy rates, inventories, and average daily room rates, we estimate that the hotel industry draws $450 million in annual revenues.[12] This number does not match the $186 million figure given in the county's tax base report, but we believe that the discrepancy is due to categorizations in the tax base report.

Material use in the visitor industry centers on inputs to hotels and fuel use in rental cars. Flows in the latter category are accounted for in the data on annual petroleum products imports. To understand the resource dependencies of hotels, we visited the largest hotel on the island, the Hilton Waikoloa Village hotel. With 1,240 guest rooms, the hotel is itself a significant stock of materials. For perspective, our estimates of the building materials used in the construction of the hotel put its mass at roughly 1.5 times that of the Empire State Building.[13]

Material flows in the hotel industry are dominated by water use. Water use at the Hilton Waikoloa for grounds keeping, laundry and custodial services, cooking, and general operations is estimated at close to 100 million liters per year. [14] Extrapolated to the entire island, we estimate that the water demand of the hotel industry on the island is equal to 8 billion liters each year, or 23 percent of the water supplied by the county. Cleaning supplies are significant, not because of the volumes in which they are used, but because of the environmental implications of improper release into groundwater or the ocean.

Oil used for electricity production is another significant input. We estimate that hotels on the island use 194 GWh of electricity each year, or 18 percent of the total electricity supplied on the

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[10] Jason Macy, Vice President/General Manager, West Hawaii Concrete, personal communication, 9 March 2006.

[11] In 2004, resident population was estimated at 162,971 and de facto population at 180,226, or an additional 10.6%. See *State of Hawaii Data Book,* 2004, "Table 1.08-- DE FACTO POPULATION, BY COUNTIES: 1990 TO 2004" and "Table 1.06-- RESIDENT POPULATION, BY COUNTIES: 1990 TO 2004." (Original source: U.S. Census Bureau).

[12] State of Hawaii, Department of Business, Economic Development, & Tourism, "2004 Visitor Plant Inventory," March 2005.

[13] Estimates based on information provided by the Hilton and by Jason Macy of West Hawaii Concrete.

[14] Simeon Miranda, Resident Manager, Hilton Waikoloa Village, personal communication, 10 March 2006.

island.[15] The other important energy-related material input is liquid propane (7.3 million liters/year).

In recent years the island has seen an increase in the number of cruise ships docking at Hilo harbor. Cruise ship passenger-days increased by 22 percent per year from 1997-2005, and the number of tourists arriving by air grew by 2.7 percent per year over the same period.[16] During their visits to the island these tourists patronize local businesses and contribute to economic activity, thus their presence contributes to the material flows of the Big Island by increasing the overall impacts of the retail sector.

5.4 Deep Sea Water[17]

Although people tend to think of pineapples or Kona coffee when they think of Hawai'i, the reality is that deep sea water, although still a nascent industry, is the island's largest export by weight. The Natural Energy Laboratory of Hawaii Authority (NELHA), a state-run agency, manages a coastal facility on the Kona side of the island that extracts deep sea water from a depth of 915 meters, running extractive pumps with a capacity of nearly 53,000 liters per minute. Several water bottling facilities have sprung up nearby, building expansive warehouses in the lava fields where they process the deep sea water through reverse osmosis.

The largest of these facilities is run by Koyo USA Corp. Koyo's purification process relies on a complex system of pumps and filters that remove minerals from the sea water and then pump it into the main bottling plant. Polyethylene pellets arrive on site in large bags and are turned into plastic bottles for the water, which is pumped in and boxed up at a rate of 100,000 bottles (150,000 liters) per day. The current plant has a capacity of 300,000 bottles per day. Koyo is set to bring an additional 700,000 bottles of capacity online by June 2006, bringing total capacity to 1 million (1.5 million liters) per day. A majority of the bottles today are exported to Japan.

The deep sea water facility is an extractive industry to the extent that a material is being removed from the place where it occurs naturally, processed, and then sold. In terms of sheer quantity the raw material -- water -- is essentially a limitless resource, but there may be as yet undiscovered environmental consequences to the extraction.

Other important inputs include energy to power the factory (276,000 L of propane and 4.6 GWh of electricity per year), plastic for the bottles (1.57 Gg/year), cardboard boxes for shipping the bottles (1.83 Gg/year), and the fixed inputs of the factory. Outputs include the exported water, packaging, and byproducts released to the environment: emissions from generation of the

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[15] Total island electricity use provided by the Yale Energy Systems Analysis team and HELCO; total hotel industry use extrapolated from Hilton figures using a 10% downward revision to account for scale.

[16] State of Hawaii Data Book, 2004. "Table 7.21a-- TOTAL VISITOR ARRIVALS BY CRUISE SHIPS AND BY AIR: 2000 TO 2004." (Original source: Hawaii State Department of Business, Economic Development and Tourism).

[17] Hiroshi Usami, General Manager, Koyo USA Corp., personal communication, 8 March 2006.

electricity, emissions from burning propane, and concentrated salt that has been extracted from the sea water. Each of these material flows will increase as plant capacity expands.

5.5 Transportation

Between vehicles, the fuels needed to power them, and the infrastructure needed to support them, transportation accounts for a significant portion of the Big Island's material flows. We record vehicle-related petroleum product material flows based on the amount of petroleum imported to the island.

The Big Island has no rail and only a single bus line, which means that it is almost entirely dependent on cars and trucks for transporting materials and people. There were a total of 168,229 vehicles registered in the Hawai'i County in 2004, including 124,632 passenger vehicles, 31,079 trucks and 3,426 motorcycles. As the island's population grows so does its personal vehicle fleet: the number of passenger vehicles on the island increased from 96,656 in 1999 to 124,632 in 2004, an increase of nearly 29% over a period in which the island's population only grew 11%.[18] The number of bicycles registered on the island has simultaneously dropped from a high of 4,551 in 2001 to only 1,223 in 2004.[19]

There is only one public bus service in the county (HELE-ON), which runs once per day between the east and west sides of the island. Each one-way trip from one side to the other takes approximately four hours and 20 minutes. Because of the long trip times and the infrequency of service the only demographic group that makes regular use of the HELE-ON system are low-income island residents, mainly immigrants from Indonesia and the Philippines, who commute to jobs in the hospitality industry on the west side of the island but live on the east side.[20] An improved and more heavily utilized public transportation system could have a dramatic impact on island material flows related to vehicle ownership and use.

5.6 State and County Government

The Hawai'i State and Hawai'i County governments are the two largest employers on the Big Island (with 7,608 and 2,291 employees respectively), and are responsible for significant materials use on the Big Island.[21] The materials purchased and used by government agencies in

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[18] *County of Hawaii Data Book*, 2004, "Table 14.7-- MOTOR VEHICLE REGISTRATION, BY TYPE OF VEHICLE, HAWAII COUNTY: 1999 TO 2004." (Original source: Hawaii State Department of Business, Economic Development and Tourism).

[19] *County of Hawaii Data Book*, 2004, "Table 14.9-- REGISTERED TAXICABS AND BICYCLES, HAWAII COUNTY: 1998 TO 2004." (Original source: Hawaii County Treasury Division and Mass Transit Agency).

[20] Mark McGuffie, Executive Director, Hawaii Island Economic Development Board, personal communication, 8 March 2006.

[21] *County of Hawaii Data Book*, 2004, "Table 11.16-- HAWAII COUNTY'S TOP THIRTY EMPLOYERS: 2004." (Original source: Hawaii State Department of Labor and Industrial Relations).

the largest quantities are cold mix, hot mix and base course for building/repairing roads, gasoline, tires, pool chemicals, herbicides, and paper/plastics.[22] Most of the materials consumed by government agencies are imported and thus accounted for in the USACE report. The only materials used by government that are extracted locally are the materials used for road construction and repair, which are also the materials purchased in the largest quantities. Estimates used in this report only include the mass of road-building materials consumed by Hawai'i County government, as information on state road construction and repair activities was unavailable. Information about the amount of materials specifically used by State and County government in other types of construction projects was also unavailable, since materials use is not tracked in government building contracts (although these materials are accounted for in the amount of construction materials used island-wide).

5.7 Water Supply

The County of Hawai'i Department of Water Supply is a semi-autonomous agency, which is responsible for managing the waterworks of the County. It is financially self-supporting through revenues collected from rate-payers, who pay an average of $0.449 per kiloliter. Water on the island is abundant, with most of the eastern half of the island receiving more than 250 centimeters of rain per year. Despite this, water supplied by the County is restricted by the fact that distribution infrastructure is limited and aging. All operating funds are used for maintenance of the existing system, with few plans and little budget available to expand the system.

Almost all water supplied on the island for non-agricultural purposes is well water drawn up from the freshwater lens that floats below the island. The water below the island is abundant and requires very little in the way of treatment compared to surface water (because it is naturally filtered by percolating through the island itself, the well water's only treatment is chlorination). There is one surface water treatment plant of note on the island, which treats and supplies 212 to 227 million liters of water a month in the Waimea/Kamuela area. The County is considering eliminating this plant in favor of deep well supplies.

The island does not have a single centralized water distribution system, but instead draws water from a series of wells and pumps that are managed by district, with 24 separate systems across the island (Parker Ranch has its own system that is privately managed). In addition, an estimated 10 to 20 percent of water supply comes from private wells, which are monitored separately by the Department of Health. There is also water supplied by a private utility, West Hawaii Utilities, in Waikoloa Village on the west side of the island. Many rural areas have no infrastructure for water supply at all and instead rely on catchment tanks. An estimated 17,900

[22] Gil Benevides, Director, Hawai'i County Purchasing, personal communication, 7 March 2006.

households depend on catchment systems, serving as much as one third of the island's residential demand.[23]

The total amount of water supplied by the County in 2005 was 34.58 billion liters, or 34,577.3 Gg. An additional 25.2 billion liters per year is taken from the ditch system, mentioned earlier, that is used by many of the island's farms.

5.8 Wastewater[24]

There are two major wastewater treatment plants (WWTPs) on the Island of Hawai'i, together emitting almost six billion liters (5,941.2 Gg) of treated effluent into the ocean each year (11.4 million liters per day on the east side and 4.9 million liters per day on the west side). There are two additional plants, but by comparison they each have very small effluent flows. The sludge from the Hilo plant (about 0.94 Gg—1032 tons—in 2005 according to county records) is currently being landfilled, although a composting program has been proposed. Sludge from the west side WWTP is kept in anaerobic digestion tanks on site, where the sludge is broken down by bacteria and converted into rich compost.

Much of the island is still off of the County's wastewater system. These users have either septic tanks or cesspools, both of which are regulated by the State Department of Public Health. Even in Hilo, only about 50 percent of residences are connected to the sewer system—a percentage which is even lower in rural areas.

5.9 Solid Waste and Recycling[25]

Despite the recent rise in development, the solid waste management system on the Island of Hawai'i is still largely that of a rural county. There is no island-wide program for curb-side collection of residential trash or recyclables, which make up 40 percent of the island's waste flow. An estimated 85 percent of residents haul to 21 "transfer stations," where they deposit their waste free of charge. Residential transfer stations consist of a chute leading down to a large trailer, which is periodically taken to the nearer of the island's two landfills (South Hilo and Pu'uanahulu) and emptied. Despite the lack of per-unit charges on waste disposal, the island still struggles to curb illegal dumping—a problem exacerbated by limited enforcement of anti-dumping laws.

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[23] Data compiled in late 2004 by the Fire Department. Available at http://www.harvesth2o.com/hawaii.shtml (28 April 2006).

[24] Woody Hingle and Mark Norman, Wastewater Treatment Plant Supervisors, personal communications, 7 March and 19 April 2006.

[25] Eileen O'Hora-Weir, County of Hawai'i Recycling Coordinator, Christopher Chin-Chance, Recycling Analyst, and Michael Dworsky, Solid Waste Division Chief, personal communication, 7 March 2006.

The other 60 percent of waste generated on the island is considered "commercial waste," which is defined as any waste which is hauled to the landfill by a private company (including some residential waste that people pay to have removed by private companies). Commercial haulers pay a tipping fee, currently set at $65 and rising to $85 by 2008. These tipping fees account for about 50 percent of the revenues used to operate the landfills. These relatively high tipping fees[26] may account for some portion of the island's illegal dumping problem, and also lead to abuse of the taxpayer-funded residential waste disposal system by commercial disposers.

The county's recycling system is relatively new. The county hired its first recycling coordinator in 2003, and has since increased its diversion rate from 12.7 percent to 30 percent (for the first half of Fiscal Year 2006). The County recycling program now includes recycling drop-off at 12 of the county's 21 "transfer stations." Diversion rate increases have been further bolstered by the 2002 passage of a state bottle bill. The bill requires that a five cent fee be assessed on beverages packaged in cans and certain bottles, which can then be returned to designated redemption centers for a refund of the fee. On the Island of Hawai'i there are now 10 such redemption centers being run at the "transfer stations" by the Association of Retarded Citizens (for the County) and two private redemption centers. The Big Island currently has two major permitted recycling companies (Atlas Recycling and Business Services Hawaii) that handle most of the non-greenwaste recycling. Of the items they accept, most cans and bottles are currently shipped off-island. A breakdown of total waste tonnages for 2005 by landfill and waste stream are given in Appendix E, and the commodities recycled and their end use markets are detailed in Appendix F. The county has set a goal of 45 percent diversion by 2025. In order to substantially increase the county's recycling capabilities, the county will need to invest in more recycling infrastructure, as well as providing financial or policy support for small recycling companies.[27]

Two years ago Hawai'i County officials estimated that the South Hilo Landfill would fill to capacity in late 2006. As of the end of March 2006 the same officials announced that the landfill could reach permitted capacity within weeks.[28] The issue of available landfill space has spurred the urgent need for the development of alternative plans or technologies to deal with the island's waste.

The South Hilo Landfill, which is unlined and does not meet current standards for the permitting of new landfills, already stands almost 61 meters high. In order to buy the landfill two to four years of additional life, the Department of Environmental Management requested that the County Council approve a proposal to increase the grade of the slopes on the sides of the landfill (an alteration that would also require a $500,000 fund balance and approval from the

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[26] The U.S. national average for tipping fees was $33.70 per ton in 2002 (see Ed Repa, "Tipping through Time," *Waste Age*, 1 Nov ember 2002, http://www.wasteage.com/mag/waste_tipping_time/index.html.)

[27] Nelson Ho, Deputy Director, Hawai'i County Department of Environmental Management, personal communication 7 March 2006.

[28] Bobby Command, "Trucking trash looms," *West Hawaii Today*, 23 March 2006.

state Department of Health). Approval of the fund transfer was made on April 5th, 2006, but a long-term alternative to disposal at the South Hilo Landfill is still needed. Among the options currently being considered is the possible installation of a waste-to-energy (WTE) facility. A request for proposals was released to try to identify viable WTE options (either incineration or gasification). Trucking of trash from the east side of the Island to the west side is also being considered, but it is a politically contentious issue and, if attempted, is sure to meet opposition. In order to avoid the possibility of trucking across the island the county is even considering the option of "bailing and shipping" trash to Washington, Oregon, or Idaho—an offer that has been made financially viable by a company that has offered to take the county's waste for $85 to $95 per ton. Trucking the waste from the east side to the west, where the landfill meets current standards and is expected to last another 40 to 45 years, would cost an estimated $55 per ton.

Recent years have seen a tremendous increase in waste production on the island, with the largest increase—over 20 percent island-wide and over 25 percent on the west side alone—taking place between 2003 and 2004.[29] This may be related in part to changes in record-keeping procedures, but almost certainly signals some change in the island's economy as well. The reason for the sharp increase appears to be unknown, but county Solid Waste Division officials attribute it to a combination of increased development on the island (resulting in construction waste) and increased affluence and consumerism, as more second-home-owners have come to the island and "big box stores" have begun to appear. Unfortunately, current record-keeping systems make it difficult to pinpoint the exact source of the growth in waste production. Many loads of waste delivered to the landfill are comprised of a mixture of waste categories and are thus categorized simply as "commercial waste," leading approximately 45 percent of all tonnage to be categorized simply as "commercial"). What *can* be determined is that the growth is primarily in this "commercial" category (between Fiscal Year 2003/2004 and Fiscal Year 2004/2004 it grew almost three times as fast as "residential" waste collected from transfer stations), and has been more rapid on the west side of the island. Both of these facts support the theories of growth in construction waste and growth in commercial packaging waste.

6 Opportunities and Challenges

Our material flow analysis has led us to consider some opportunities for improving the sustainability of Big Island industrial operations.

Agriculture

With a substantial amount of land on the Big Island owned by agricultural concerns, and with land prices rising, the agricultural industry is faced with the opportunity to seek higher-value uses for its land. These alternative uses may also contribute to the long-term sustainability of the island. Parker Ranch, for example, has a small amount of electricity generating capacity in a hybrid solar/wind electricity plant. It sells some of its power to a co-located cement batch plant

[29] Based on data collected at the County's two landfills by Solid Waste Division officials.

facility. Opportunities to take advantage of the island's solar and wind energy potential, while leveraging the land assets of the agricultural industry, look promising.

Another potential higher-value activity for the agriculture industry involves identifying and capitalizing on a new market niche for agricultural products. As the base of visitors and vacation residents continues to grow on the island, there will be a growing segment of the market that would respond favorably to organic, locally-farmed produce, and would be willing to pay the premium necessary to offset the relatively higher labor and equipment costs of agricultural production on the Big Island.

Finally, green waste from agriculture (particularly timber harvesting) could be sold to one of the power generation facilities on the island that is capable of turning biomass into energy.

Construction

The construction industry on the Big Island shows great potential for vastly increased materials efficiency. One obvious opportunity is increasing the recycling rate for construction and demolition (C&D) waste. This may include the recycling of concrete, metal rebar, brick, glass, and other materials—a full assessment of what, if any, materials are already being recovered is needed in order to identify the materials with the most unmet recycling potential. Another option for increased materials efficiency is the use of recycled materials in new buildings, which would provide the needed market for recovered/diverted construction waste. Recycled waste products could be used in place of imported virgin materials—for example the use of crushed glass as an alternative for sand in road sub-surfacing or recycled plastics or paper products as building insulation. Supporting the need for enhanced markets for recycled C&D materials may require changes to the County Building Code and government incentives for the use of these materials. Addressing the need to increase the recycling of C&D waste may go a long way in addressing the island's growth in waste production overall, as most of the growth appears to be "commercial," and is likely to associated with the construction industry.[30] In addition, there may be potential for the construction industry to use its significant volume of wastewater as a raw material for other industries; West Hawaii Concrete is already looking at the option of recycling wastewater through desalinization and co-location with an agricultural facility, which could use the water for irrigation while providing natural filtration.[31]

Visitor Industry

As mentioned earlier, hotels on the Big Island are significant consumers of energy and material resources. Water use, energy use, and construction are main areas of concern and opportunity. The industry is relatively concentrated: thirty-one hotels account for 65 percent of the hotel rooms on the island. Hotels, therefore, have significant purchasing and decision-making power. An island-wide commitment by the industry to renewable energy standards,

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[30] Based on data collected at the County's two landfills by Solid Waste Division officials.

[31] Jason Macy, Vice President/General Manager, West Hawaii Concrete, personal communication, 9 March 2006.

construction standards, or water reclamation could have a large impact on material uses in these areas. For example, hotel kitchens could make a commitment to sourcing food products locally, stimulating the local agricultural markets and reducing reliance on imported food.

The Mauna Lani Bay Hotel recently installed rooftop solar panels to improve its energy consumption profile. The neighboring Hilton Waikoloa occupies 26 hectares of land on the sunny west side of the island, and is perfectly positioned to follow suit. Hotels on the island could begin to look for opportunities to leverage real estate assets in creative ways. High oil prices and resultant high electricity costs will make these opportunities more and more feasible from a financial standpoint.

Over one half of the Hilton's monthly water demand is used in grounds keeping and landscaping operations. Keeping golf courses and green vegetation alive on the dry west side of the island requires frequent watering. Enhanced used of "gray water" irrigation systems and plant species that require less water would reduce not only the demand on the water table but also the energy required to pump water from wells to ground level.

NELHA

In addition to the Deep Sea Water bottling facility, numerous small businesses are currently being incubated at the NELHA site on the Kona coast. Deep sea water extracted from the ocean is being used to support projects in aquaculture, pharmaceutical and beauty products, agriculture, and temperature regulation. Some of these projects have the potential to decrease energy use or increase on-island use of local materials. The facility has the potential to become an eco-industrial park, with different production factors sharing water resources and byproducts. Koyo, for example, extracts salt from the ocean during reverse osmosis and currently pumps it back into the ocean. A co-located facility could turn these salts into a high-value beauty product.

Transportation

The ever-increasing number of cars and the island's poor transit system are a challenge faced by the county. Increasing alternative transportation options could have a significant impact on material flows, as it could result in a decrease in personal vehicle use, thus decreasing the need for imported gasoline. It is even possible that improved public transportation options could lead to a decrease in personal vehicle *ownership*, which would additionally impact the materials associated with car production and the energy used to ship new and used cars to the island. A functional transit system could also lessen the dependence of island tourists on rental cars, further reducing the consumption of vehicle-related materials on the island.

The fact that the island's population is so widely dispersed also contributes to dependence on car use. Addressing development patterns on the island through support for denser, more walkable and bikeable communities could also change transportation patterns on the island.

7 The Impacts of Materials Transportation

As we have shown, the Big Island is highly dependent on sea-borne material inputs. We estimate that between 65 percent and 76 percent of the island's material inputs are imported by barge or container ship.[32] Different industries rely on these inputs to varying degrees, but it is widely known that any disruption in barge service would be felt across the entire island.

A high degree of dependence on imports leads not only to vulnerabilities but to externalities. The island's extensive material imports guarantee that a constant stream of barges and cargo vessels is plying the waters of the Pacific Ocean heading to or from Hilo and Kawaihae harbors.

The bulk of consumer products are shipped through Honolulu. The Jones Act, a provision within the U.S. Merchant Marine Act, requires (among other things) that cargo being shipped between two U.S. ports be shipped in a U.S.-owned and operated ship. As a result, much of the cargo that arrives in Hawai'i from abroad is shipped first to Honolulu on a foreign ship, off-loaded, and then loaded back onto American-owned inter-island ships.

A comprehensive analysis led by the EPA offers some insight into the amounts of criteria air pollutants that are emitted by ocean-going vessels under a variety of conditions.[33] Actual emissions resulting from this extra cargo handling and from the ocean-going vessels that transport cargo to the Big Island depend on a complex of factors including cargo load, type of ship, amount of time spent idling, sea conditions, traveling speed, the age of the engine, and more. For the purposes of this analysis, we make the qualitative claim that there are significant hidden material flows and externalities that result from a high level of material imports.

Any changes from the status quo, whether they involve an increase on-island industry leading to greater exports, an increase in imports, or an increase in local demand leading to greater local production, must be approached within the constraints of the island's infrastructure: harbors and docks, unloading equipment, storage warehouses, trucks for on-island distribution, and roads. Both the Hilo and Kawaihae ports are currently running at high utilization rates, with Kawaihae looking into the possibility of adding dock space to accommodate not just additional cargo ships but also a new high-speed ferry that may start arriving from Maui.[34] Material distribution around the island depends on a system of narrow and often hilly roads. The marginal impact of any additional industrial activity, therefore, is significant.

As an example, one of the biggest objections to a proposed wood pulp operation has been the increase in traffic along the road between the timber forest and the port of Hilo whence the wood would be exported.[35] The impact of the deep sea water bottling facility has already been

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[32] Ian Birnie, Hawaii District Manager, Hawaii DOT, personal communication, 9 March, 2006; USACE report.

[33] U.S. EPA, "Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data," Report ID EPA420-R-00-002, February 2000.

[34] Ian Birnie, Hawaii District Manager, Hawaii DOT, personal communication, 9 March 2006.

[35] John Tew, Product Development Manager, Fulghum Fibres, personal communication, 8 March 2006.

noticed along the road to Kawaihae harbor. Infrastructure issues are a key consideration when it comes to altering material flows on the island.

8 Conclusions and Future Research

The Big Island of Hawai'i is still a relatively rural island, with little natural resource extraction taking place locally and minimal primary processing or manufacturing happening on the island. Because of this and other factors, the island's material inflows are dominated by the importation of most of its material inputs. This unique material use profile also leads to the particular set of environmental and sustainability challenges that arise from an economy that has become heavily reliant on the service and tourism/hospitality industries.

As a point of comparison, we analyzed county and national averages for the Big Island and for the U.S. in three categories. Economic measures in two important industries reveal that construction and hotel revenues, both scaled by population, are significantly higher on the Big Island than national averages. It will be critically important to manage development in these sectors responsibly. The third measure, materials recycling, puts the Big Island behind the national average, and below regional leaders.[36]

Table 3: Comparison to Mainland U.S.

	Big Island	U.S.
Construction (2004 USD/cap)[1]	3,804	1,963
Accommodations (2004 USD/cap)[2]	1,141	360
Recycling Rate (2004 percentage)[3]	20	28.5

[1] HI Institute for Public Affairs; US BEA.

[2] DBEDT; US BEA.

[3] HI County Solid Waste Division; BioCycle Sate of Garbage in America report.

To understand better the material flows of the island, more detailed and accurate research is needed on the impacts of the west side of the island's rapid growth. Better information on the construction materials used in—and the waste produced by—the construction industry would be especially important, as well as how development trends are likely to change over the coming decades. More research is also needed on where opportunities might exist to substitute more local resources, especially recycled resources, for materials that are currently being imported. This could include opportunities for facility co-location and industrial symbiosis, as outlined in section 6.

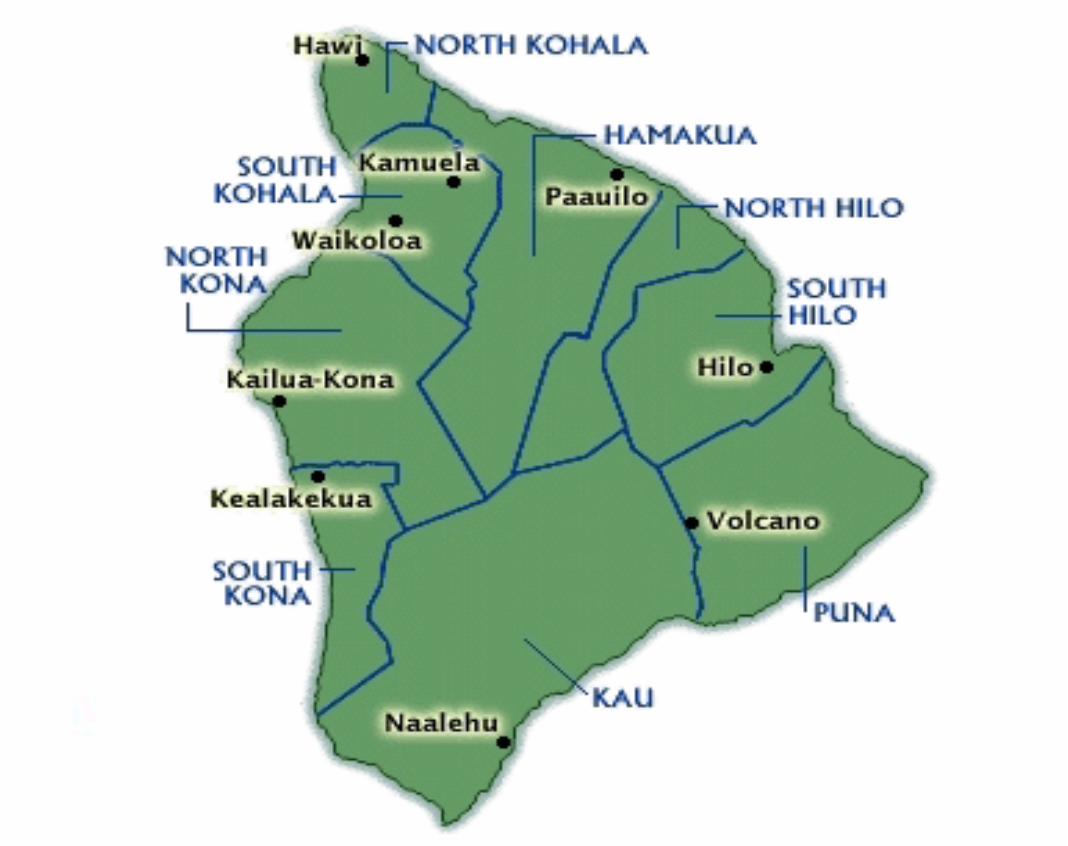
But even as research of the island's materials use continues, one thing is already clear: the Island of Hawai'i has a tremendous set of opportunities to improve its material efficiency. The next step will require creativity, political savvy, an ability to engage the Big Island's residents, and a commitment on the part of Hawai'i and its leaders to the pursuit of a sustainable future.

[36] San Francisco, for example, diverts nearly 50% of its municipal waste stream for recycling. See http://www.sfenvironment.com/articles_pr/.

Appendix A: List of Interviews

Name	Title	Organization
David Stark	Plant Controller	Hershey's / Mauna Loa Macadamia Nut Corp
Guy Cellier	President	Forest Solutions
John Tew	Project Development Manager	Fulghum Fibres
Lorie Farrell	Manager	Big Island Farm Bureau
Christopher Chin-Chance	Recycling Specialist	Hawaii County - Solid Waste Division
Gil Benevides	Director of County Purchasing	Hawaii County
Nelson Ho	Deputy Director	Hawaii County - Department of Environmental Management
Daryl Ikeda	Chief of Operations	Hawaii County - Department of Water Supply
Woody Hingle	Superintendant	Hilo Wastewater Treatment Facility
Hiroshi Usami	General Manager	Koyo USA Corp
No one in particular	N/A	NELHA
Mark McGuffie	Vice President	Kona-Kohala Chamber of Commerce
Pete Hoffman	Councilman	N. Kohala/Waimea/Waikoloa/Puako
Ian Birnie	Hawaii District Manager	Hawaii DOT - Harbors
Chauncey Wong Yuen	Hawaii District Manager	Hawaii DOT - Airports Division
Simeon Miranda	Resident Manager	Hilton Waikoloa Village
Rudy Habelt	Director of Property Operations	Hilton Waikoloa Village
Maurice Kaya	Chief Technology Officer	DBEDT
Jason Macy	VP/General Manager	West Hawaii Concrete
Corky Bryan	VP, Livestock Operations	Parker Ranch
Kyle Datta	Senior Director	Rocky Mountain Institute

Appendix B: The Nine Districts of Hawai‘i County

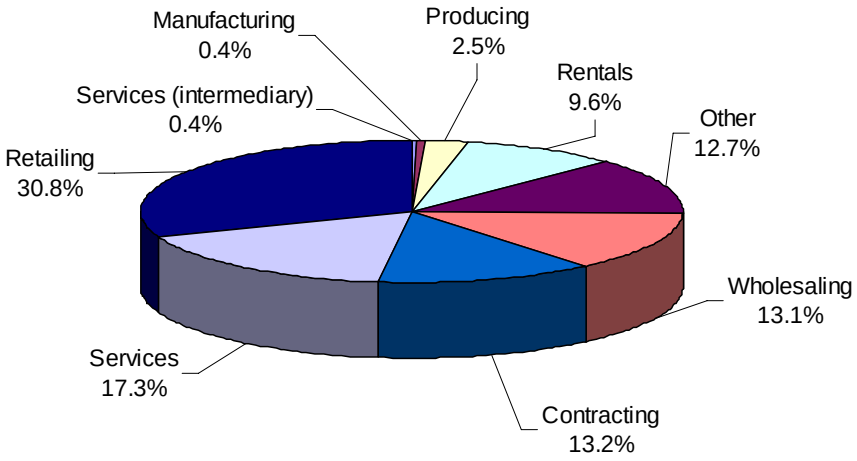


Map source: American Dream Realty, http://www.adrhi.com/graphics/hse_map_hawaii.gif.

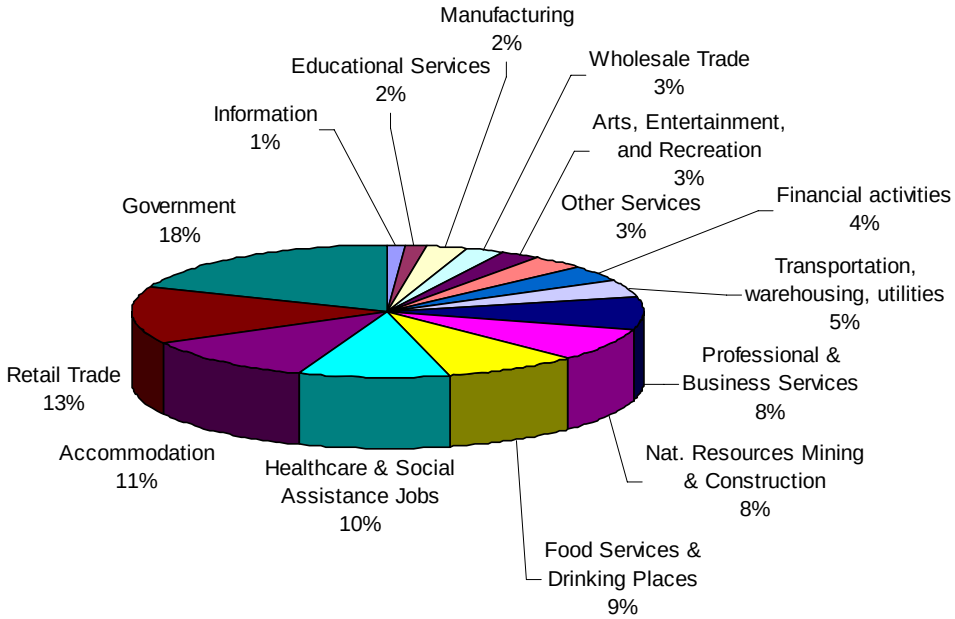
Appendix C: Big Island Economic Activity

(Source: Hawaii County Data Book.)

Big Island Tax Base by activity (2004)



Big Island employment by economic activity (Fourth Quarter 2005)



Appendix D: Table of Material Flows

	Category Name	Mass of Flow (Gg)	Key Data Source(s)	Assumptions Used
Imports	Machinery	200.2	US Army Corps of Engineers, 2003, "Waterborne Commerce of the United States." (See Appendix A)	Includes receipts in the following categories: "machinery (not electrical)," "electrical machinery," "vehicles & parts," "aircraft & parts," "ships & boats," "ordnance & accessories." Numbers shown in this report are derived from published 2003 numbers, grown to 2005 numbers at a rate equal to the weighted 9-year compound annual growth rates for Hilo and Kawaihae harbors. Masses in Gigagrams are calculated from numbers of short tons rounded to the nearest 1000 tons.
	Misc. Products	238.5	Extrapolated from 2003 US Army Corps of Engineers data.	Includes receipts in the following categories: "plastics," "manufactured wood products," "textile products," "rubber & plastic products," "manufactured products nec."
	Food	269.0	1) Extrapolated from 2003 US Army Corps of Engineers data. 2) Hawaii State Department of Transportation, Airports Division. "Airport Activities Statistics(annual)"	1) Includes receipts in the following categories: "fish," "grain," "vegetable products," "processed grain and animal feed," and "other agricultural products." 2) Includes all products reported as having been deplaned.
	Petroleum Products and Chemicals	407.4	Extrapolated from 2003 US Army Corps of Engineers data.	Includes receipts in the "total petroleum and petroleum products" category (381.1 Gg) and receipts in the following categories: "fertilizers," "medicines," "perfumes & cleansers," "pesticides," "explosives," "chemical products nec.," "forest products nec.," "soil & fill dirt" (totaling 26.3 Gg).

	Construction Materials	1494	Extrapolated from 2003 US Army Corps of Engineers data.	Includes receipts in the following categories: "pigments & paints," "lumber," "sand & gravel," "non-metal minerals nec.," "cement & concrete," "glass & glass products," "misc. mineral products," "fabricated metal products," "iron & steel bars & shapes," "iron & steel pipe & tube," "primary wood products."
Domestic Resources	Volcanic Rock	430.9	1) County purchasing data for road-building materials 2) Extrapolated from 2003 US Army Corps of Engineers data on amount of cement imported 3) Personal communication with Jason Macy of West Hawaii Concrete	1) Assumes that full weight of road-building materials other than oils and sand is locally extracted "rock." 2) Assumes a 2.4:1 ratio of rock to cement in concrete (as communicated by Jason Macy), and that all cement entering the island is mixed into concrete.
	Sand	275.2	1) County purchasing data for road-building materials 2) Extrapolated from 2003 US Army Corps of Engineers data on amount of cement imported 3) Personal communication with Jason Macy of West Hawaii Concrete	1) Assumes that the only sand included in road-building materials is labeled as such. 2) Assumes a 3.6:1 ratio of sand to cement in concrete (as communicated by Jason Macy), and that all cement entering the island is mixed into concrete.
	Deep Sea Water	109.5	Personal communication with Hiroshi Usami, General Manager of Koyo USA Corp.	Based on number of liters of water bottled daily at the Koyo plant; subject to change in conjunction with Koyo's capacity expansion.

Additions to Stock	Machinery	200.2	Same is in imports section.	Same as in imports section.
	Misc. Products	238.5	Same is in imports section.	Same as in imports section.
	Road Building and Construction	1939.9	1) County purchasing data for road-building materials 2) Extrapolated from 2003 US Army Corps of Engineers data 3) Personal communication with Jason Macy of West Hawaii Concrete	1) Includes all extracted rock and sand (see assumptions above) 2) Includes all imported construction materials
Exports	Manufactured Products	1078.9	Extrapolated from 2003 US Army Corps of Engineers data.	Includes shipments in the following categories: "petroleum and petroleum products," "chemicals and related products," "primary manufactured goods," "manufactured equipment, machinery, and products."
	Agricultural Products	100.0	1) Extrapolated from 2003 US Army Corps of Engineers data 2) Hawaii State Department of Transportation, Airports Division.	1) From USACE includes shipments in the "food and farm products" category. 2) Assumes that all shipments by air are perishable agricultural products.
	Crude Materials	22.1	Extrapolated from 2003 US Army Corps of Engineers data.	From USACE includes shipments in the "crude materials, inedible except fuels" category.
Wastes	Landfilled - Residential	79.3	County Department of Environmental Management, Solid Waste Division records (see Appendix B)	Converted from tonnage from all residential "transfer stations" to both landfills

	Landfilled - Commercial	125.1	County Department of Environmental Management, Solid Waste Division records	Converted from all tonnage tipped and paid for by commercial haulers at both landfills.
	Landfilled - Cover	217.7	County Purchasing Department estimate of cover material purchased annually	Assumes a conversion factor of 1.5 tons per cubic yard, as per estimate offered by workers at the landfill through personal communication on April 10th, 2006.
	Air	875.2	Calculated from 2003 US Army Corps of Engineers data on petroleum product imports, and data on electricity generation provided by the Yale energy systems analysis.	Based on emissions from combustion of gasoline and fuel oil. Gasoline component assumes 8.9kg of CO2 per gallon of gas burned (Source: Congressional Budget Office). Fuel oil/electricity generation component assumes 1688 lbs of emissions per MWh generated, primarily CO2. We then weight the resultant 3,209 Gg by (12/44), based on the molecular composition of CO2, so as not to include oxygen extracted from the air during combustion (Source: fueleconomy.gov).
	Land + H_2O	83.1	USACE report; Hiroshi Usami, Koyo USA Corp, personal communication.	Assumes that fertilizers and other imported chemicals are released to the environment in use. Also includes the portion of deep sea water that is extracted and then returned to the ocean.
	Recycled	30.8	County Department of Environmental Management, Solid Waste Division records (see Appendix C)	Includes all diverted materials. Of the 30.8 Gg of diverted materials, 22.5 Gg (73 percent) are organic/greenwaste.

Appendix E: 2005 Solid Waste Categories and Tonnages

South Hilo Landfill	
Commodity	**Tonnage**
Asbestos	0
Bar Screen	76.02
BISM Hilo-Debris	4.56
Boiler Ash	0
CH Highways	0
CH Parks-Mnt	1218.66
CH Roads	46.93
CH Roads - No Chg	0.01
CH Transfer Stn	41028.76
Clear/Grub	78.62
Commercial	29743.58
Confidential Doc.	8.42
Constr. Debris	7819.54
Contaminated Soil	0
Cut Tires	556.84
Cut Tires - No Fee	40.73
Dead Animal	5.24
Div - Crushed Glass	64.2
Divert G.-Non Return	0
Divert-Green (Raw)	23996.25
Divert-Metal (Scrap M.)	5403.24
Divert-Pallets	0
Fish Carcass	331.5
Flourscent lights	0
Glass Uncrushed	25.92
Green Waste	79.78
Hilo T/S - AL	0
Hilo T/S - OCC	19.12
Hilo T/S - Glass	5.79
Hilo T/S - News	29.85
Hilo T/S - WL	0
Keaau T/S Glass	95
Keaau T/S Greenwaste	764.54
Keaau T/S Metal	322.29

Pu'uanahulu (west side) Landfill	
Commodity	**Tonnage**
Asbestos-SH	435.24
Bar Screen-Grit	39.42
Boiler Ash	15.17
CH Other Depts.	75.05
CH Transfer Stn	46366.46
Clean Up-Hilo Burrito	0
Clear/Grub	0
Commercial	85001.97
Confidential Doc.	0.34
Constr. Debris	21.63
Contaminated - Other	0
Contaminated Soil	1048.03
Cut Tires - No Fee	0
Cut Tires (Fee)	0
Dead Animal	96.73
Empty Drums	0
FiberGlass & Insulation	0
Filter Cake (HELCO)	3.55
Fish Carcass	273.45
Flourscent lights	0.08
Green Waste	0
Green Waste-Oversized	0
Marijuana	1.26
Meat Trimmings	0
Medical Ash	3.37
Medical Waste SH	13.49
Oil Filters	5.77
Other Govt. Agencies	66.21
Other Rubbish	0
Outdated Foods	14.92
Outdated Liquor	64.81
Removal-County-Appl.	6.12
Residential	771.44
Restaurant Grease	187.07

Keaau T/S Cardboard	42.13
Keaau T/S Mixed Paper	3.29
Keaau T/S News	7.17
Keaau T/S Paper	0
Keaau T/S Plastics	3.56
Legal Bury	8.04
Medical Waste	32.87
Offal/Waste	620.83
Old/Off Specs	111.88
Redemption	5.23
Atlas - AL	354.96
Atlas - OCC	783.45
Atlas - Plastic	73.41
Redemption - ARC	877.44
Redemption - Hilo	225.61
Redemption - Kea`au	150.1
Redemption - Pahoa	88.85
Redemption - Waimea	150.56
Redemption - Kealakehe	129.83
Redemption - Keauhou	19.04
Redemption - Puako	41.27
Redemption - Hawi	13.63
Redemption - Waiohinu	58.55
Residential	880.47
Sludge	1031.6
TOTALS	**116601.7**
Diverted - Glass	-64.2
Diverted - HMR/EKO	-24037
Diverted - Metal	-5403.24
Hilo T/S Diversions	-54.76
Keaau T/S Glass	-95
Keaau T/S - Green	-764.54
Keaau T/S - Metal	-322.29
Keaau T/S - Cardboard	-42.13
Keaau T/S - Paper	-10.46
Keaau T/S - Plastic	-3.56
Atlas - AL & OCC & Plastic	-1211.82
Redemptions - Total	-882.67
BISM Hilo-Debris	-4.56
TOTALS	**83705.5**

Divert. - Scrap Metal	1091.99
Special Grease - N/C	0
Sludge	764.01
Water Base Paint	0
Green Waste - N/C	0
Divert - Pallets	0
TOTALS	**136367.6**
Diverted	-1098.11
TOTALS	**135269.5**

Appendix F: End Use Destinations of Recycled Commodities

Commodity	Destination	End Use Markets:
Glass	On-Island	Crushed and used as construction fill, landscaping and some very small art/craft uses. On-Island Brewery reuses its bottles, but this is a very small percentage of overall glass recycling.
Greenwaste	On-Island	Mulch for public/private use (currently). Proposed composting facility to combine biosolids, pallets, greenwaste and greasetrap waste remnants.
Latex Paint	On-Island	Local reuse/exchange - paint swap, donations to community groups for beautification projects or sale of commingled paint for reuse.
Reuse/Exchange	On-Island	Reuse/Exchange Center for people to bring/take items they want/need. Also regular fundraising auctions of "Still Good Stuff." County does not track commodities reused by private organizations such as the Salvation Army or Goodwill.
Used Motor Oil	On-Island and Off-Island	Recycled and or processed.
Paper Fibers	2.3% On-Island, 97.7% Off-Island	142 tons or 2.3% is shredded for agricultural packing. Remainder of mixed paper goes to West Coast US recyclers, and cardboard goes to Asian markets.
Cooking Oil	Off-Island	Biodiesel production within the State of Hawai'i.
E-Waste	Off-Island	West Coast US recycler deconstructs and recycles all materials in EPA compliant manner.
Household Hazardous Waste	Off-Island	Company properly disposes/recycles of hazardous materials.
Metals Scrap & Etc.	Off-Island	Scrap metal from autos, white goods & etc. goes to East Asia markets (China). Recycled food containers & etc. goes to West Coast US sort station for recycling.
Mixed Recyclables	Off-Island	West Coast US sort station.
Plastics	Off-Island	Plastics from categories #1 & #2 collected through the County of Hawai'i programs go to the West Coast US. End market not reported to County analyst.
Tires	Off-Island	Crumbed and sent to West Coast US.

Hawai'i Island currently has just two major companies (one with multiple sister companies) that handle most of the non-greenwaste recycling/diversion on the island. There are about eight other companies/organizations that deal with one or more of the recycled commodities, with most specializing in one commodity.

Source: Christopher Chin Chance, Recycling Analyst, County of Hawai'i, "Re: Question related to fate of recycled materials." Email to the author. 20 April 2006.