Carbon flux and Storage - State and Island level

The impact on climate change for each human use and land is expressed in comparable units through the CO_2 equivalents.

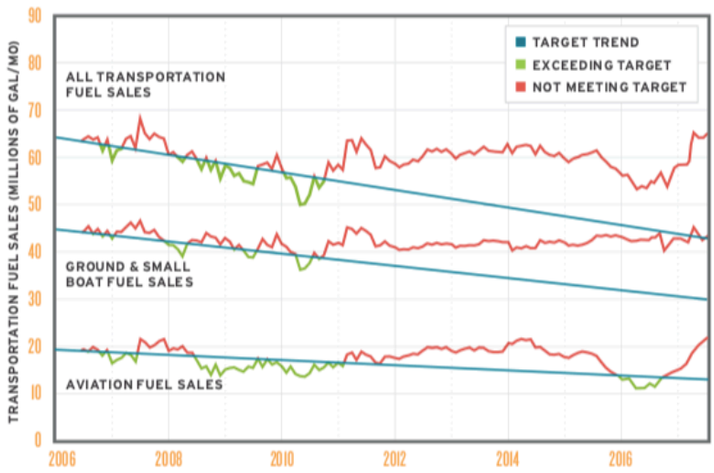
STATE & ISLAND LEVEL million metric tons of CO_2 equivalent ($mmtCO_2eq$)							
	State	**Oahu**	**Hawaii**	**Kauai**	**Maui**	**Molokai**	**Lanai**
Population[1]	1,361,790	953,207	186,738	66,921	144,444	7,345	3,135
Land area (acres)[1]	4,034,560	382,080	2,577,920	353,280	465,280	166,400	89,600
FLUX - Annual emissions minus annual sequestration							
Electric power[2]	10.18	6.77	0.77	0.35	0.78	0.05	0.02
Transport[2]	9.79	9.25	1.28	0.54	1.38	0.09	0.04
Food[3]*	3.49	2.44	0.48	0.17	0.37	0.02	0.01
Stuff[3]*	4.02	2.90	0.47	0.18	0.41	0.02	0.01
Waste[2]	0.78	0.72	0.14	0.07	0.13	0.01	0
Land use							
Livestock, ag, forest fires[2]	1.05	0.09	0.48	0.1	0.13	0.01	0.1
Grassland[4]	0.81	0.02	0.66	0.03	0.06	0.01	0.02
Urban trees[2]	-0.4	-0.4	no data	no data	no data	no data	no data
Shrubland[4]	-0.96	-0.07	-0.57	-0.08	-0.08	-0.11	-0.04
Forest[4]	-1.96	-0.23	-1.11	-0.23	-0.25	-0.08	-0.05
TOTAL NET EMISSIONS / YR	**26.8**	**21.49**	**2.59**	**1.13**	**2.93**	**0.02**	**0.11**
Long term carbon storage							
Forest[4]	143.79	19.03	92.63	0.03	21.25	6.77	4.09
Shrubland[4]	22.31	1.84	14.67	0.01	2.05	2.78	0.97
Grassland[4]	51.97	1.48	44.16	0.01	4.31	0.78	1.22
Soil / other land[4]	5.70	0.02	5.34	0.00	0.29	0.03	0.01
TOTAL STORED	**223.77**	**22.36**	**156.80**	**0.05**	**27.91**	**10.35**	**6.30**

*Mostly imported.

Sources

1 - https://energy.hawaii.gov/wp-content/uploads/2011/10/ghg-inventory-20081.pdf
2 - ICF International for DBEDt December 31 2008 (2007 for all island level data)
https://health.hawaii.gov/cab/files/2019/02/2015-Inventory_Final-Report_January-2019-004-1.pdf (2015 for State level data only)
3 - coolclimate calculator, UC Berkeley
4 - CAH USGS study 2017

Transportation is the sector responsible for the most emissions and the sector we are making the least progress on.



Fuel sales are presented as a six-month moving average of monthly gasoline, highway diesel and LPG, small boat gasoline and diesel, and aviation fuel sales, as reported by the State of Hawai'i Department of Business, Economic Development & Tourism or Department of Taxation, and assume that non-fossil-based transportation fuel sales to date have been negligible in comparison to overall sales. Energy independence target trends assume that fossil-based transportation fuel sales decrease linearly from the 2006 monthly average to zero gallons by 2040. Some information in the accompanying text is from the 2015 Hawai'i Clean Energy Initiative Transportation Energy Analysis.

PRIMARY METRIC

FOSSIL-BASED MOTOR FUEL SALES

Transportation accounts for almost two-thirds of our fossil fuel consumption, making sustainable mobility solutions essential to moving Hawai'i beyond oil. In the past year, demand for transportation fossil fuels has increased. We are not on track.

Ground Transport powered by electric grids or batteries

How much electricity does it take to move different vehicles?
This table shows how much electricity (kWh) different vehicles require to take a passenger the same distance. Price is determined by price of electricity. Solar electricity costs are falling sharply. Even at 2014 prices, it was already cheaper to fuel an electric vehicle than a fuel-efficient gas car in Hawaii.

	Electricity 100 passenger km (kWh)
Connected directly to grid	
Light rail train	3.5
Metro	4
Commuter train	4.8
Trolley bus	4.8
Electric battery	
e-bike	1
e-scooter	2.5
e-rickshaw	4
e-motorbike	4.8
e-car (high occupancy)	4-6.5
e-car (low occupancy)	8.4-11
e-bus	2.5

Considerations for batteries:

1. It is more efficient when vehicles are connected directly to the grid via wires or contact with the ground instead of using batteries. Electric trains, trolleys and buses already use such systems, and new systems are being designed. For example, in Rapid Urban Flexible transport, guideways can be set up on freeways that power trains of cars from the grid until they detach to use local roads with their own battery.
2. Batteries use minerals such as lithium, nickel and copper which have limited reserves and the mining process may result in environmental pollution.

What is going on now in Hawaii?

- **Vehicles** – 1.3 million cars, buses, trucks and motorcycles registered in Hawaii. The average Honolulu motorist spent 60.8 extra hours in traffic in 2013.
- **Miles driven** in Hawaii has increased. Despite this, driver emissions have gone down due to use of electric vehicles, hybrids and more fuel-efficient cars. In 2015, there were 3,478 electric vehicles in Hawaii and sales have continued to grow.

- **Commute to work** - On Oahu, 67% of commuters drive themselves, 14% carpool, 7% use public transit, 5% walk, 5% work at home, and 4% use other means of travel. On Oahu 71% jobs are in the urban core and 46% of the population lives there.
- **Bus** – Most popular alternative to driving, but rides are decreasing on Oahu. Rides a year: Oahu (77.3 million), Maui (2.4 million), Kauai (781,790), Hawaii (920,280).
- **Bike** - Bike-sharing in Honolulu has 4,500 riders a day. New bike paths being built.
- **Rail** – a 20-mile elevated electric rail from Kapolei to Honolulu is under construction. Predicted 121,000 riders/day.

Short term actions planned for Oahu:

- Expand electric charging infrastructure
- Subsidize low income residents to retire inefficient vehicle and replace them with cleaner options.
- Make the city fleet run on renewable fuel - buses, trucks and cars.

https://www.honolulu.gov/rep/site/ccsr/Ola_Oahu_Resilience_Strategy.pdf#page=41

Ground, Marine and Air Transport powered by biofuels or hydrogen

Some ground transport (heavy trucks, farm equipment and emergency vehicles), and all marine and air transport have fuel needs that cannot be met by electric batteries or the electric grid.

What renewable technology exists now?

- Hydrogen or biofuels can be used to power fuel cells or adapted internal combustion engines for aircraft, boats and heavy land vehicles.
- Biofuels take energy from biomass (living or recently living matter and byproducts) and can replace fossil fuels. The plants take in carbon as they grow, and that carbon is releases back to the atmosphere when the fuel is burned, so it does not add new carbon to the atmosphere. They can be used with little or no modification by engines and distribution systems made for fossil fuels.
- US renewable fuel standards require all gasoline sold in the US to mix in 10% Ethanol which is made from corn or other crops.
- US renewable fuel standards requires biodiesel made from plant oil or animal fats to be mixed in, making up about 3% of diesel sold. All diesel engines can take up to 5% blended biodiesel, and with slight modifications, they can take up to 20%. Most biodiesel is made from soy, rapeseed, and oil palm dominate the current market for biofuels, but it can also be made from waste such as used cooking oil, municipal waste, algae and grasses.
- Airplanes can use bio-jet which is made like biodiesel but then processed with hydrogen to remove all the oxygen. More than 180,000 commercial flights have used biojet, but it is less than 1% of jet fuel used. It is currently over 4 times the price of conventional jet fuel.
- Hydrogen is made by splitting water into oxygen and hydrogen. If the energy used to split the water is renewable, then the hydrogen is also renewable. Processing hydrogen fuel from start to finish requires twice as much energy as the hydrogen actually gives off. While it is not very energy efficient, it is in a form that can be transported and used by vehicles with high energy needs.
- Biogas is a mixture of methane and CO_2 that is chemically similar to natural gas but instead of being made over millions of years by nature, organic matter (including garbage and sewage) is processed with pressure and heat. Further processing can turn it from gas to liquid and into pure forms that can be used by jets and other vehicles.
- Solar may be used for small planes.
- Solar may be used in combination with battery storage and diesel generators for marine transport.

https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy

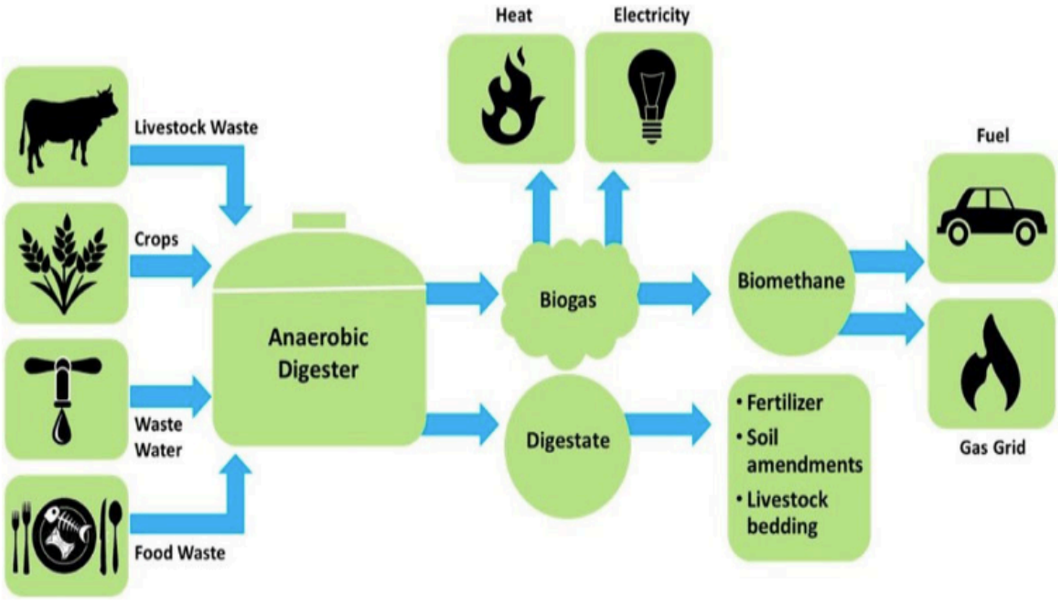


Figure 1: Anaerobic digestion process

https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy

What are the costs of different renewable fuels?

	$/gallon
Biodiesel (20% blend)	2.88
Biodiesel	3.51
Ethanol (85% blend)	2.31
Biojet	16
Hydrogen fuel	5.6*
Hydrogen fuel (price in near future)	3.4*

*gasoline equivalent (actually sold by kg, not gallon)

Considerations for biofuels:

1. Biofuels are not renewable if they use wood biomass from a forest that was an existing carbon sink.
2. Biofuels from food crops directly compete with other land uses like forests or food agriculture. When the government requires amounts of biofuels to be mixed into diesel supplies that exceeds waste sources, then vegetable oils are diverted to this use instead of food. Palm oil fills the gap and palm oil plantations in Southeast Asia have destroyed rainforests and animals that lived in them.
3. Biofuels can be obtained from fermentation of farm and urban wastes or from burning waste cooking oil. However, there is a limited supply of waste.
4. Biofuels may be made from algae, potentially with much higher yield per acre, but cost of production must be brought down to be competitive.
5. Biogas or methane can be captured from sewage treatment facilities, garbage landfills and dairies (animal manure). This uses the greenhouse gases that are escaping into the air anyway, instead of using fossil fuels that would be taken out of the ground. Biogas has been used widely for 50 years in India and China, and is now being used in Europe and the US on a large scale. A by-product of biogas is natural fertilizer which can replace fertilizers that are currently made from fossil fuels.

Considerations for hydrogen fuel:

1. Producing hydrogen uses platinum which has limited reserves and the mining process may result in environmental pollution.
2. To use hydrogen for ground or marine transport requires investment in hydrogen infrastructure for production, storage, transportation and port services. Japan is already investing heavily in hydrogen infrastructure for ground transportation.

What is going on in Hawaii already?

- **Hydrogen fuel** – The technology is well established and there are fleets of hydrogen cars in use at military facilities on Oahu. The fuel for those fleets is produced on site.
- **Biofuels used** – They are mixed into all gasoline and diesel as required by law. Hawaii County uses a 20% biodiesel blend (B20) in buses, fire trucks, and ambulances. Honolulu uses B20 for garbage trucks and ambulances.
- **Biofuels made from plant biomass** – None are used directly for transport, but 4 electric plants on Oahu and one on Hawaii use biofuels used oils and animal fats, unused cooking oil and locally grown crops. A project on Kauai uses woodchips from locally grown eucalyptus, albizia, and other agricultural (waste) biomass to generate electricity. A handful of projects grow feedstock such as sunflowers and two are developing techniques to produce algae.
- **Biofuels made from sewage** – Hawaii Gas invested $5 million on equipment to capture and process gas from Honouliuli Wastewater Treatment Plant for use in their gas pipelines starting December 2018. It makes up about 3% of the total gas sold on Oahu. They will buy the 800,00 therms of gas from the City of Honolulu at $2/therm which generates new income for the City. There are 19 additional centralized wastewater treatment plants in Hawaii that are not capturing gas. The fuel is not being used for transportation. Honolulu's HPOWER collects sludge from 7 of 9 wastewater treatment plants on Oahu, but it is burned to create electricity from the heat, not as biofuel.
- **Biofuels made from garbage –** Biogas from landfills can captured and processed for biofuel. Hawaii Air National Guard Waste-to-Energy Microgrid System Demonstration project on Hawaii uses agricultural and municipal waste to create syngas for electricity. The project plants to hydrogen to fuel vehicles and liquid aircraft fuel. Kauai County invested $4.17 million in Kekaha landfill gas collection and control system consisting of collection wells, piping and an enclosed flare facility to reduce greenhouse gas emissions and to collect methane. They proposed purchasing public buses that could run on methane and fueling them from the landfill in the future.
- **Interisland travel** - While in some places air travel is being replaced with high speed rail, that is not possible for and island chain like Hawaii. The "Super Ferry" sought to replace some interisland air travel in 2009. Legal and financial problems led to bankruptcy.

What is the best way to get Hawaii all the way to 0 emissions for all transport?
What are the trade-offs between costs and benefits?

Don't forget that efficiency, urban planning and shifting modes of transport for people and goods can play a role.

Cost of Using Fossil Fuels

Hawaii sends almost $4 billion annually out of the State to purchase fossil fuels. Funds spent on fossil fuels do not contribute to the economy in Hawaii. Also, dependence on oil makes the State vulnerable to oil price fluctuations. 2017 purchases[1]**:**
$3,757,000,000 - oil
$46,000,000 - coal
$91,000,000 - natural gas

There are many current and expected financial costs to Hawaii associated with climate change. These include damage to coastal infrastructure from sea level rise and storm surges. Damage to property due to increase storms and flooding. Increased temperatures and decreases in trade winds result in the need to install and use more air conditioning. Lost agricultural productivity. Decline in Hawaii's fisheries as a result of coral reef damage. Declines in tourism due to more frequent extreme weather and damage to our shoreline and reefs.

Dependence on fossil fuels makes Hawaii vulnerable to port closures due to natural disasters or military conflict. Ports closed briefly during Tropical Cyclone Olivia in 2018.

There is a risk of accidents and oil spills that could negatively impact wildlife in the ocean as well as seabirds on the surface of the ocean. Over 1,000 oil spills have been documented since 1960.[2]

Burning fossil fuels results in smog, acid rain, soot and particulates increase, greenhouse gas emissions, and dispersal of some heavy metal contaminants. These are harmful to human health, especially for people with respiratory ailments such as asthma.[3] You can calculate caused or avoided pollution here. http://www.cleanerandgreener.org/resources/pollutioncalculator.html

How does your solution compare to continuing to use fossil fuels?

[1] (www.eia.gov)
[2] https://www.livescience.com/9885-faq-science-history-oil-spills.html
[3] https://www.epa.gov/nutrientpollution/sources-and-solutions-fossil-fuels