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

Use Less Electric Power, or More?

Using less power is the easiest first step
Hawaii has "Energy Efficiency Portfolio Standards" which mandate a 30% reduction in electricity use through efficiency measures from 2008 to 2030. Hawaii has invested over half a billion dollars in these efforts, saving money in the long run and exceeding targets set.

The State has used financial incentives to encouraged individuals, businesses and state agencies to invest in energy efficient appliances, and improve infrastructure such as lighting, plumbing and air conditioning to save energy and water.

Laws now require new homes to include solar water heaters since heating water makes up 35% of home electricity bills. Installation of hot water heaters was previously subsidized. Building codes have also been changed to include energy efficient designs.

If transportation is to be powered by renewable electricity, then total production will need to go up dramatically no matter how efficient we are.

Renewable Electric Power

Switching power production to renewable sources
The renewable portfolio standard mandates 100 percent renewable energy in the electricity sector by 2045. In 2017 Hawaii still generated most of its electricity from imported oil (68%) and imported coal (14%).[1] Local, renewable power is already cheaper and costs continue to decline as technology improves. However, renewable energy requires existing infrastructure that manages and distributes the power to be adapted and new infrastructure to be built. In addition, electricity is a regulated industry and new renewable energy projects like wind or solar farms must go through a lengthy process of approval by the Public Utilities Commission.

The proportion of electricity from renewable sources is lowest on Oahu (19%) and highest on Kauai (44%). Most of the demand for electricity is on Oahu. The opportunities and costs for renewable power generation are different on the different islands. Some have proposed connecting islands with an undersea cable to bring more renewable power to Oahu. Others worry about negative environmental and social impacts on islands producing energy for Oahu and potential harm the electric cables would have on marine mammals. In the short run the electric utilities are focused mostly on solar, wind and battery storage. Only when they cannot use oil power plants to smooth out supply do they plan to switch some plants to biofuels.

What are the costs of different fuel types?
Prices are shown in cent/kWh – how many cents it costs to produce a certain amount of power. Older HECO contracts that must be completed include prices over 20 cent/kWh, but costs are decreasing rapidly and recent power purchase prices have been:

Large scale solar and battery storage[2]	8 cents/kWh
Rooftop solar (installed with subsidies)[3]	7 cents/kWh
Wind	4 cents/kWh
Oil	15 cents/kWh
Geothermal	10 cents/kWh
H-power	18 cents/kWh
Imported biodiesel	32[4] cents/kWh

[1] www.eia.gov
[2] **https://www.hawaiianelectric.com/six-low-priced-solar-plus-storage-projects-approved-for-oahu-maui-and-hawaii-islands**
[3] https://www.uhero.hawaii.edu/assets/WP2015-4.pdf
[4] https://www.hawaiianelectric.com/documents/billing_and_payment/rates/energy_cost_adjustment_filings/oahu/2019/oahu_ecrc_2019_02.pdf

H-POWER (Honolulu Program of Waste Energy Recovery), owned by the City & County of Honolulu, processes the solid waste from Oahu and burns it in furnaces to produce steam that drives a turbine generator. The electricity is sold to Hawaiian Electric and distributed to customers. H-POWER is not renewable energy but it avoids the emissions of methane that would otherwise result from the waste rotting in the landfill. H-POWER also reduces the volume of refuse that goes to the landfill by 90%.

Starting Point for New Solutions

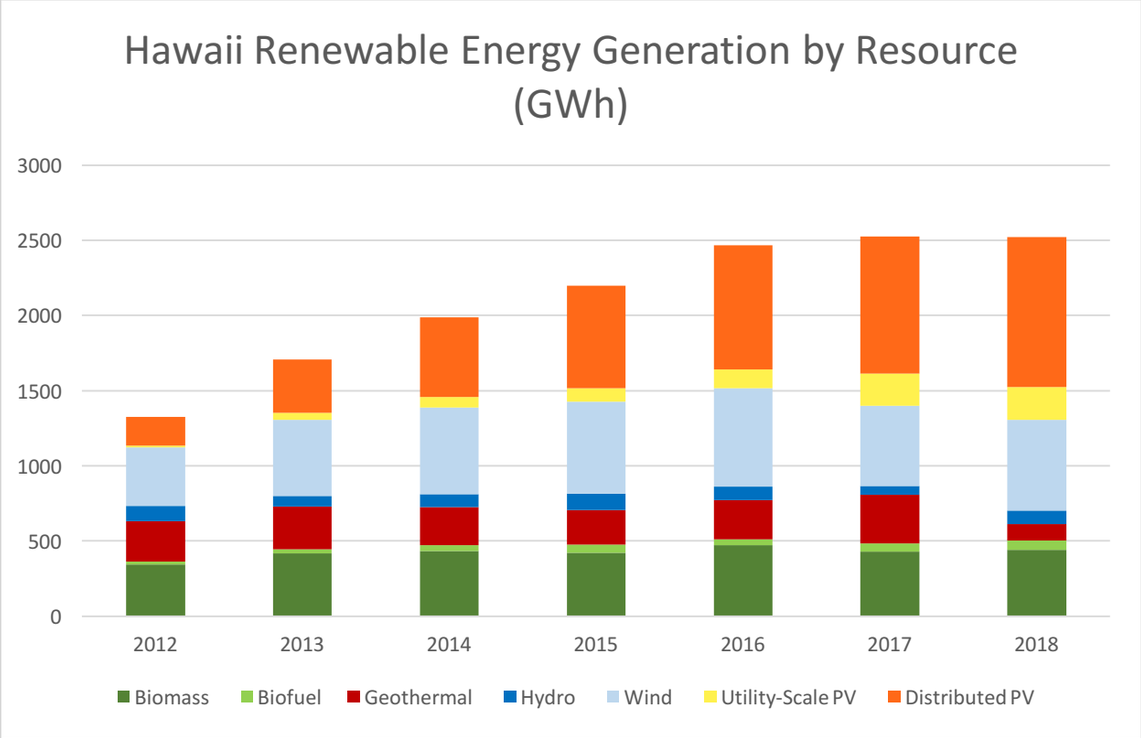
Renewables existing and in the works:

	renewable 2016, MW	added renewable by 2021, MW or MWh (storage)	% renewable energy 2021
Oahu[5]	406.9 rooftop solar 18.5 feed in tariff* 99 large wind 11 large solar 68.5 biomass	255.1 rooftop solar 23.8 feed in tariff 64 large wind 352.2 large solar 69.5 battery storage	37%
Molokai	1.2 rooftop solar	1.4 rooftop 5 large wind 0.3 battery storage	100%
Lanai	0.8 rooftop solar 1.2 large solar	0.7 rooftop solar 4 large wind 0.1 battery storage	52%
Maui	97.9 rooftop solar 5.6 feed in tariff 72 large wind 0.5 hydro	38.4 rooftop solar 1 feed in tariff 62 large wind 6.7 large solar 10.8 battery storage	50%
Hawaii	88.3 rooftop solar 2.4 feed in tariff 31 arge wind 16.6 hydro 38 geothermal	30.3 rooftop solar 5.7 feed in tariff 22 large wind 1 large solar 56.1 battery storage	63%
	2018		**2025**
Kauai [6]	31.3 rooftop solar 44.6 large solar 4.3 hydro 6.7 biomass 52 battery storage	34 large solar 31 hydro	82%

*feed in tariff are suppliers under 5 MW who sell solar or wind energy as available to HECO
The amount of energy produced is measured in megawatts (MW).

Total potential for distributed rooftop solar (HECO and Google estimates)[7]: Oahu – 3,200 MW, Maui – 524 MW, Hawaii – 456 MW.

[5] https://www.hawaiianelectric.com/documents/clean_energy_hawaii/grid_modernization/dkt_2014_0183_20161223_companies_PSIP_update_report_1_of_4.pdf
[6] http://website.kiuc.coop/renewables
[7] **https://www.hawaiianelectric.com/documents/clean_energy_hawaii/grid_modernization/final_august_2017_grid_modernization_strategy.pdf**



Geothermal production decreased in 2018 due to plant closure caused by volcanic eruptions.[8]

Best Fit Power Sources

Location

Check out the type of renewables that would work for your community on this map. You can click on critical habitat, reserves and special management areas to see places where use is restricted because it is critical habitat or provides other benefits. For biomass you can look at the layer agricultural lands of importance to consider conflict with food production.
http://geodata.hawaii.gov/energis

For maps of location of HECO facilities and projects see:
https://www.hawaiianelectric.com/clean-energy-hawaii/clean-energy-facts/about-our-fuel-mix
Are there some projects that would be best located near a power plant?

Considerations for intermittent power

- The infrastructure and distribution system of the utility companies was built with power sources that were available all the time. Solar and wind are intermittent and inconsistent. The utilities want to make sure they can meet sudden demand, or make up for a sudden loss in intermittent power. Since the older, lower cost power plants cannot start up their fossil-fuel based production quickly, they need to leave plants running. Solar is particularly problematic because peak production is during the day while peak demand is in the evening.
- HECO estimates that between 2018 and 2023 it will invest $254 million to modernize the grid so it can integrate and stabilize the uneven production of distributed renewable energy like rooftop solar that does not match demand cycles.[9]
- Excess energy produced during the day can be used to charge batteries, to charge hydrogen fuel cells, to move water uphill so that the energy is stored for later.
- Cost of batteries have come down quickly. Minerals like lithium and nickel are needed for batteries and they have limited reserves and the mining process may result in environmental pollution.
- 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

8

[9] **https://www.hawaiianelectric.com/documents/clean_energy_hawaii/grid_modernization/final_august_2017_grid_modernization_strategy.pdf**

fuel from start to finish requires twice as much energy as the hydrogen actually gives off. While it is not very energy efficient, it can be stored in cells to be used as needed. Producing hydrogen uses platinum which has limited reserves and the mining process may result in environmental pollution.

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.

- **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. 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.

Environmental considerations for other forms of renewable energy

- **Windmills** kill some birds and bats. To protect endangered birds and bats, all proposed wind energy projects must first assess the possible risk to endemic native birds and the Hawaiian hoary bat. They also require that projects obtain incidental "take" permits under the Endangered Species Act and develop and implement habitat conservation plans that include mitigation for unavoidable harm to birds and bats.[10] Some places are off limits to windfarms, including the entire island of Kauai. Bird deaths are still a big problem for both the birds and for energy production because they need to turn off the windmill when a certain number of birds have been killed. New technologies that warn windfarm operators or warn the birds may help.[11]
- **Solar** panels do not mix well with trees. There can be conflict between access to sun on rooftop panels and urban trees. Solar farms may also compete for land with forests and agricultural land.
- **Geothermal** operations bring up hazardous chemicals that are then put back in the ground as fluids, but some escapes. There may be negative health effects.[12]

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[10] https://abcbirds.org/to-protect-birds-and-bats-from-wind-turbines-adopt-hawaiis-approach/
[11] https://www.audubon.org/magazine/spring-2018/how-new-technology-making-wind-farms-safer-birds. https://www.popsci.com/acoustic-lighthouse-alerts-birds-to-wind-turbines/
[12] http://www.accord3.com/docs/Report%20FINAL.pdf

Developing new renewable sources of energy in Hawaii
The Natural Energy Laboratory of Hawaii Authority is a test site for experimental renewable energy generation methods and pilot plants for them. Originally built to test Ocean thermal energy conversion (OTEC), it later added research into other sustainable uses of natural energy sources such as aquaculture, biofuel from algae, solar thermal energy, concentrating solar and wind power.

What is the best way to get Hawaii all the way to 0 emissions for all power sources?

What are the trade-offs between costs and benefits?

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