Hawaii Clean Energy Initiative

Electricity and Transportation Wedge Analysis

Scenarios to illuminate policy needs and inform technical working groups

Washington D.C.
June 11, 2008

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- Introduction and Summary
- Eight Scenarios - Results
- Appendix

The purpose of the analysis is to show various ways that Hawaii's resources can be deployed to reach the 70% clean energy goal

- The analysis illuminates various ways that Hawaii's supply and demand side resources can be used to reach 70% clean energy (Note: this is not an optimization exercise; it does not pick the best scenario based on lowest cost, lowest greenhouse gas emissions, or similar metric)
- The scenarios include efficiency, electric generation, and transportation, but do not analyze energy delivery needs (grid upgrades, energy storage, etc.)
- The working groups will be able to use these scenarios to determine which policy changes will be needed to encourage different types of clean energy investment (e.g., solar PV) at sufficient scale

Key conclusions

- **Renewable resources**: All types of electricity generating technologies need to be deployed to reach 70% (wind, solar, geothermal, biomass, hydro, etc.)
- **Efficiency**: Aggressive energy efficiency measures are likely to be critical to achieving the 70% clean energy goal
- **Cable**: The state is unlikely to reach 70% clean energy for electricity and maintain high levels of clean energy for transportation unless there is a cable to Oahu from the outer islands; the cable explored in this analysis is a shallow cable to Oahu from Lanai and Molokai
- **Electric vehicles**: While the number of electric vehicles on the road in 2030 has only a modest impact on the state's electricity demand, high levels of electric vehicles are needed if the transportation sector is to reach high clean energy goals

The analysis is sensitive to a few important assumptions—which can be further examined

- **Plug-in hybrid electric vehicle (PHEV) efficiency assumptions**
  - 0.32 kWh per mile driven (Source: EPRI/Argonne)
- **Use of biodiesel in generating units**
  - 650,000 gallons per year of petroleum liquids—residual fuel, jet fuel, distillate fuel oil, and kerosene (roughly energy equivalent to biodiesel) are needed to produce 1 MW over a year (Source: DOE/EIA)
- **Level of in-state biodiesel and ethanol production**
  - A maximum achievable potential of 50% of the 428 MGY ethanol potential and 50% of the 161 MGY biodiesel potential, given constraints of food production and other land uses. These lands are assumed to be overlapping, so only ethanol *or* biodiesel can be fully deployed to this 50% level for any one scenario (Source: HARC Biodiesel Crop Implementation for Hawaii, HNEI Potential for Ethanol Production in Hawaii)
- **Solar potential figures for rooftop PV installations**
  - 2 kW per home on 50% of Hawaii's homes, 100 kW per commercial building on 50% of Hawaii's commercial buildings (Source: adopted from California Solar Resources Report)

The analysis explored eight scenarios to test the effect of energy efficiency levels, PHEV penetration, biofuels, and inter-island cabling

	Transportation: Maximize ethanol production and use all biofuels for transportation; low PHEV penetration	Transportation: Maximize biodiesel production and use biodiesel for electricity needs on Oahu; high PHEV penetration
Moderate Efficiency ("Maximum Achievable Potential" from utility IRPs)	**1** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels for transportation (only ethanol) Low PHEV	**3** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - no cable Biofuels fill in Oahu electricity to 70% (only biodiesel) High PHEV
	2 Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels for transportation (only ethanol) Low PHEV	**4** Kauai loaded by economics (limit CSP to 14 MW) Hawaii loaded by economics (limit geo to 60 MW) Maui loaded by economics (limit geo to 42 MW, deploy 3 MW ocean) Oahu resources loaded by economics - cable from Lanai, Molokai Biofuels fill in Oahu electricity to 70% (only biodiesel) High PHEV
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Note: Grey boxes have an inter-island cable

Summary of results for the eight scenarios

	2030 End-state for Each Scenario (installed capacity)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Efficiency	220	220	220	220	495	495	495	495
Biomass - direct firing	93	93	120	120	56	56	83	83
Wind	276	1076	276	1076	223	1023	260	1060
Geothermal	102	102	102	102	102	102	102	102
Hydro	36	36	40	40	24	24	24	24
Solar (residential roofs)	182	182	205	205	166	67	179	179
Solar (commercial roofs)	633	633	712	712	578	232	622	622
Solar (utility scale)	29	29	29	29	22	22	29	29
MSW	77	77	79	79	77	77	77	77
Ocean energy	53	53	53	53	53	3	53	53
Dispatchable	271	271	301	301	235	235	261	261
Non-dispatchable	1209	2009	1316	2116	1065	1370	1167	1967
Electricity Sector Clean Energy %	**46%**	**65%**	**46%**	**63%**	**58%**	**70%**	**57%**	**70%**
Oil reduction (million bbls in 2030)	10.0	14.0	11.5	15.5	12.5	15.1	14.0	17.3
CO_2 avoided (million tons in 2030)	5.1	7.2	5.9	7.9	6.4	7.7	7.2	8.8
Transportation Sector Clean Energy %	**30%**	**30%**	**57%**	**57%**	**30%**	**30%**	**57%**	**63%**
Oil reduction (million bbls in 2030)	4.7	4.7	9.0	9.0	4.7	4.7	9.0	9.9
CO_2 avoided (million tons in 2030)	2.0	2.0	3.8	3.8	2.0	2.0	3.8	4.2

Note: All electricity sector numbers are in total installed capacity needed; transportation sector includes only ground transportation

***Example observation**: While Scenarios 2 and 6 show similar results, they employ different means. Scenario 2 uses less energy efficiency and requires much more solar capacity; also its ratio of non-dispatchable to dispatchable electricity is 7.4, whereas Scenario 6 relies more on energy efficiency (and is likely to cost less) and has a non-dispatchable to dispatchable ratio of 5.8*

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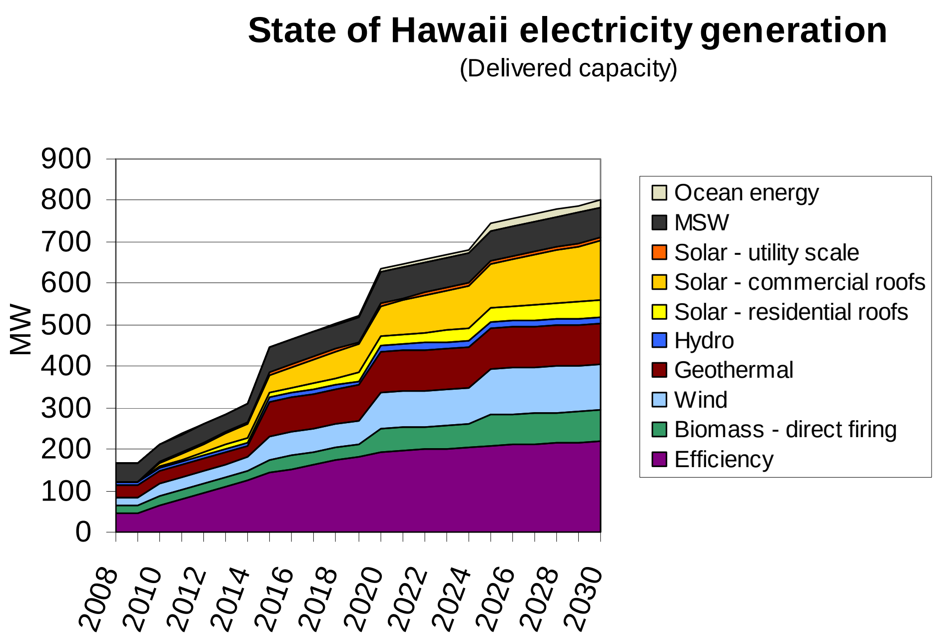
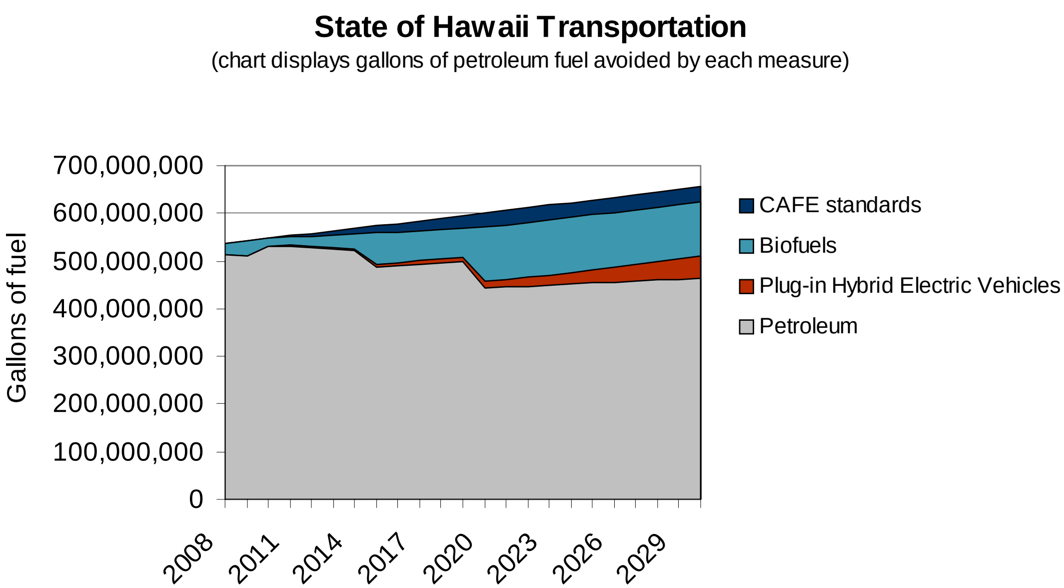
Scenario 1 Electricity - Moderate efficiency, low PHEV penetration, and no cable connecting the islands



Summary of 2030 Electricity Results	
Clean energy achieved	*46%*
Oil reduction (million bbl/yr)	*10.0*
CO2 avoided (million ton/yr)	*5.1*

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the utility Integrated Resource Plans (IRPs); clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (36% without imports); no cable; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by commercial and residential rooftop solar (183 MW delivered capacity), as well as geothermal, wind, and biomass. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

Scenario 1 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



Summary of 2030 Transportation Results	
Clean energy achieved	***30%***
Oil reduction (million bbl/yr)	***4.7***
CO2 avoided (million ton/yr)	***2.0***

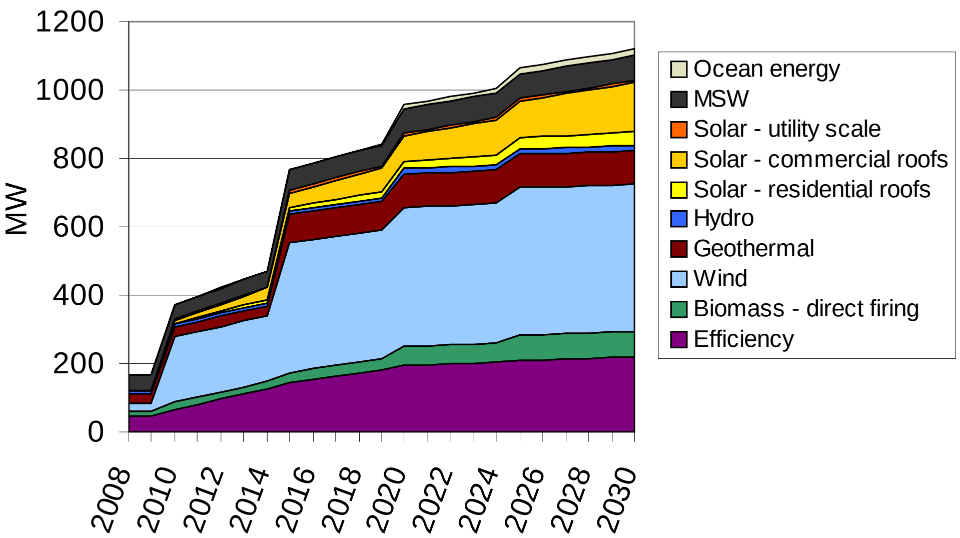
- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030**;** biodiesel is imported to meet the RFS

- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

Scenario 2 Electricity - Moderate efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai

State of Hawaii electricity generation

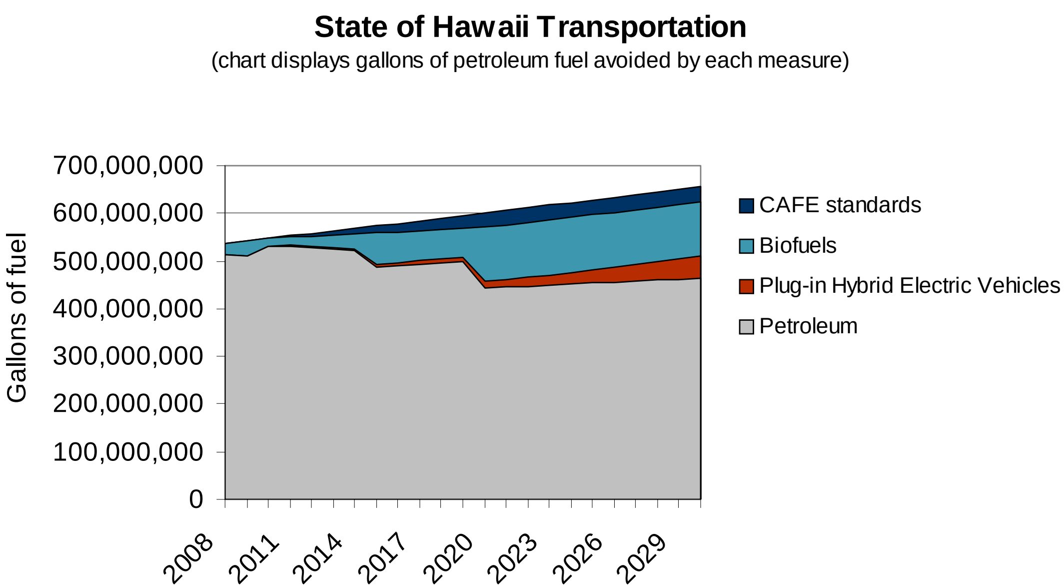
(Delivered capacity)



Summary of 2030 Electricity Results	
Clean Energy Achieved	***65%***
Oil reduction (million bbl/yr)	***14.0***
CO2 avoided (million ton/yr)	***7.2***

- **DESCRIPTION:** Energy efficiency to the level of “maximum achievable potential” as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (36% without imports); cable connecting Oahu to Lanai and Molokai; biofuel resources used for transportation fuels; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (431 MW delivered capacity). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

Scenario 2 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation

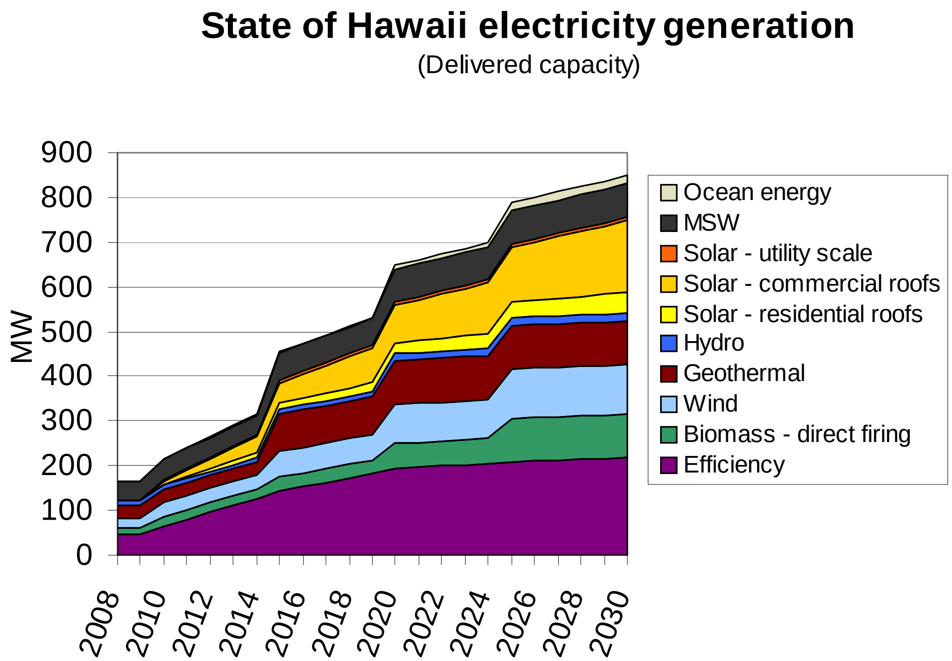


Summary of 2030 Transportation Results	
Clean energy achieved	***30%***
Oil reduction (million bbl/yr)	***4.7***
CO2 avoided (million ton/yr)	***2.0***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS

- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

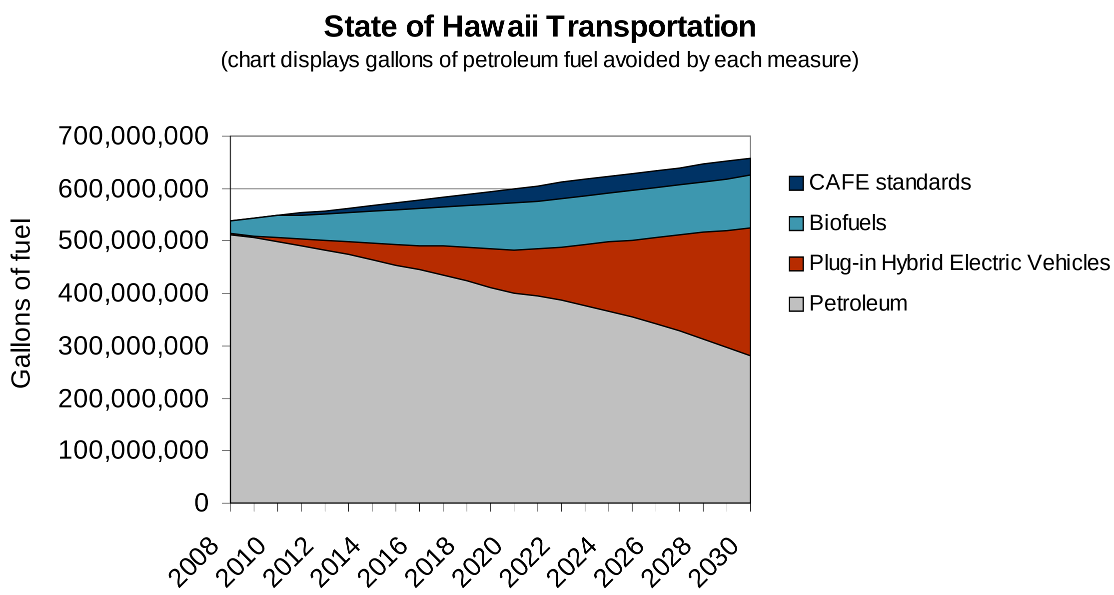
Scenario 3 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and no cable



Summary of 2030 Electricity Results	
Clean energy achieved	***46%***
Oil reduction (million bbl/yr)	***11.5***
CO2 avoided (million ton/yr)	***5.9***

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (32% without imports); no cable; PHEVs at a high penetration level
  - Oahu would require 352 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 46%
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (206 MW combined), as well as geothermal, wind, and biomass. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

Scenario 3 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%

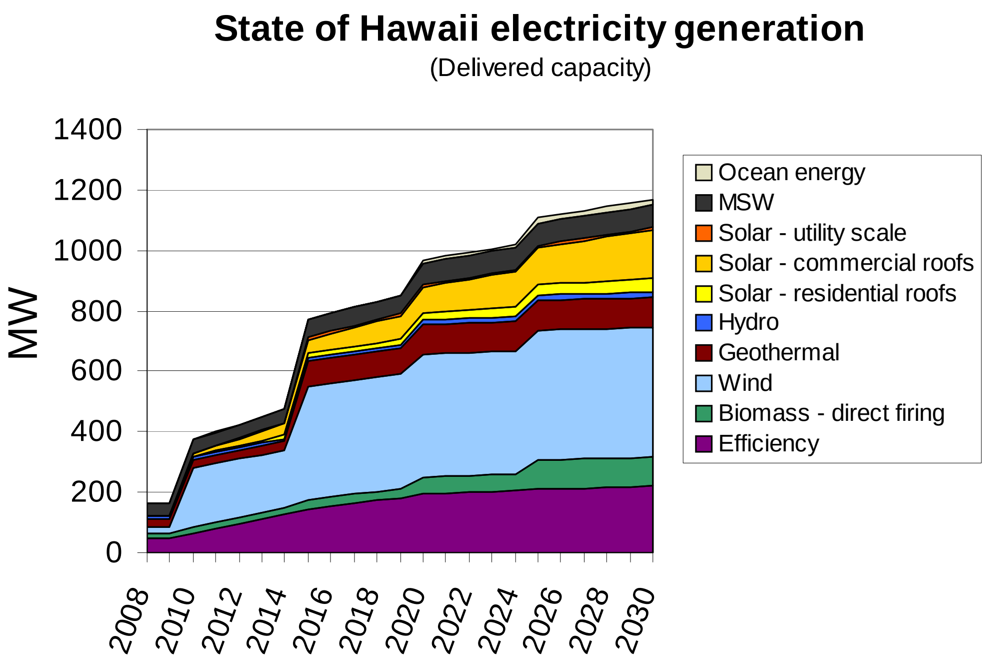


Summary of 2030 Transportation Results	
Clean energy achieved	***57%***
Oil reduction (million bbl/yr)	***9.0***
CO2 avoided (million ton/yr)	***3.8***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity; ethanol is imported to meet the RFS

- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

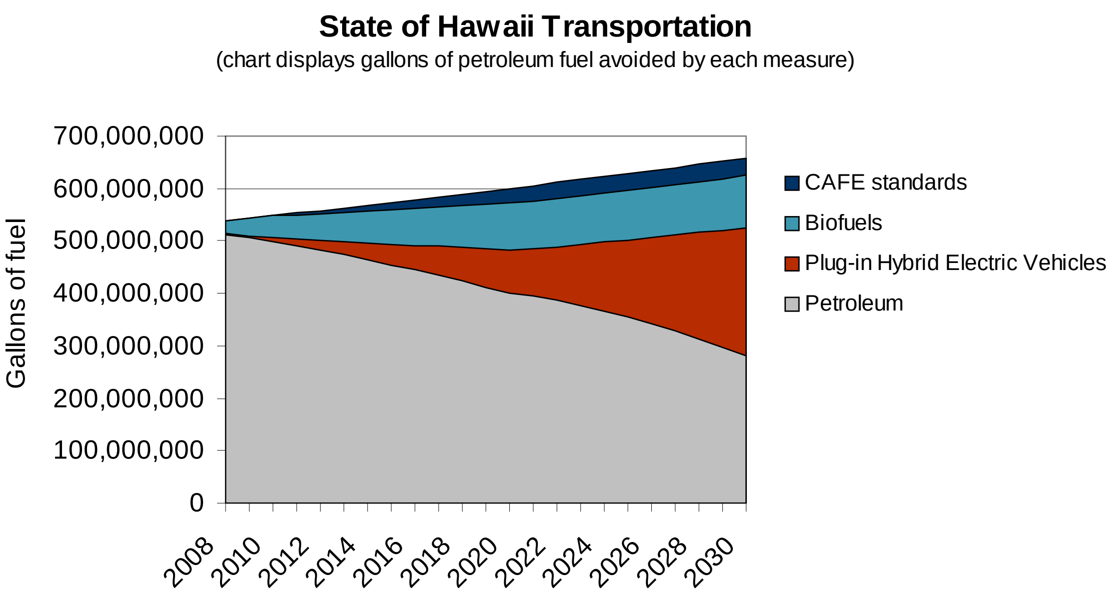
Scenario 4 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and a cable to Oahu from Lanai and Molokai



Summary of 2030 Electricity Results	
Clean energy achieved	***63%***
Oil reduction (million bbl/yr)	***15.5***
CO2 avoided (million ton/yr)	***7.9***

- **DESCRIPTION:** Energy efficiency to the level of "maximum achievable potential" as defined in the IRPs; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (32% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a high penetration level
  - Oahu would require 139 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 63%
- **RESULTS:**
  - Energy Efficiency: Under the "maximum achievable potential" estimates in the utility IRPs, demand side management measures would decrease statewide electricity demand by 220 MW (13% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (431 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

Scenario 4 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%

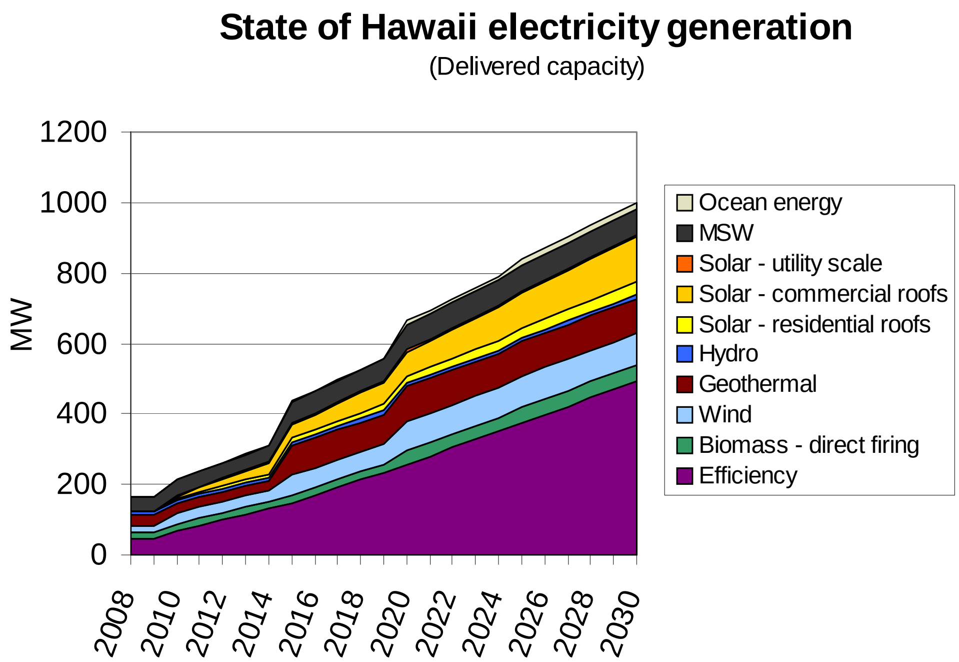


Summary of 2030 Transportation Results	
Clean energy achieved	***57%***
Oil reduction (million bbl/yr)	***9.0***
CO2 avoided (million ton/yr)	***3.8***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity; ethanol is imported to meet the RFS

- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

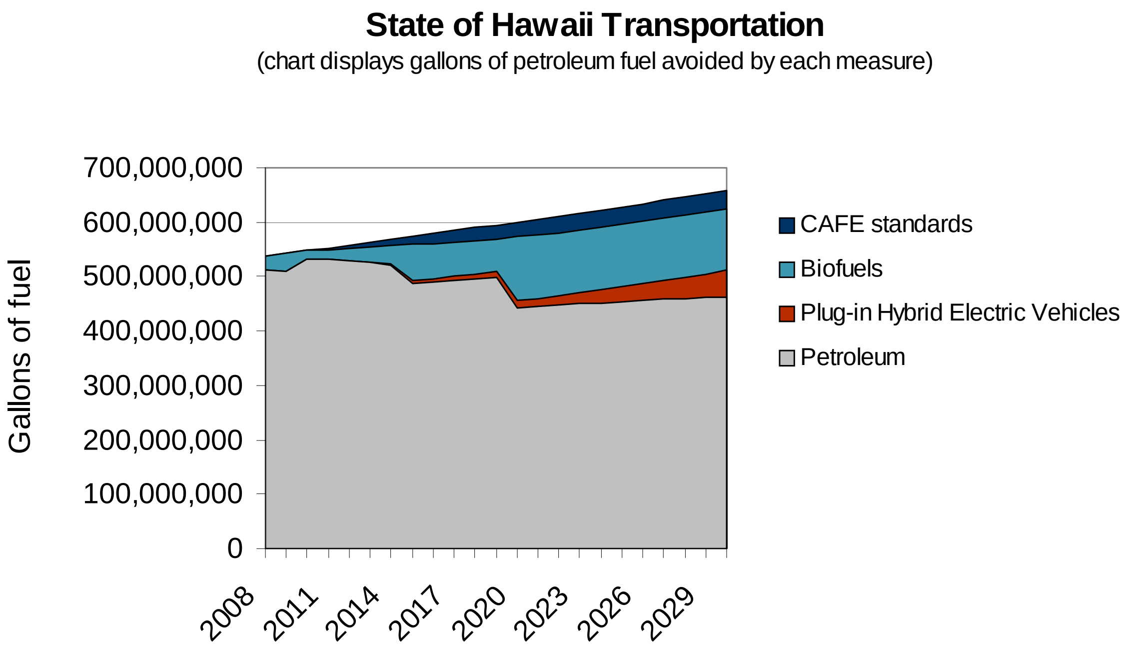
Scenario 5 Electricity- High efficiency, low PHEV penetration, and no cable connecting the islands



Summary of 2030 Electricity Results	
Clean energy achieved	***58%***
Oil reduction (million bbl/yr)	***12.5***
CO2 avoided (million ton/yr)	***6.4***

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (53% without imports); no cable; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (165 MW combined), as well as geothermal, wind, and MSW. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

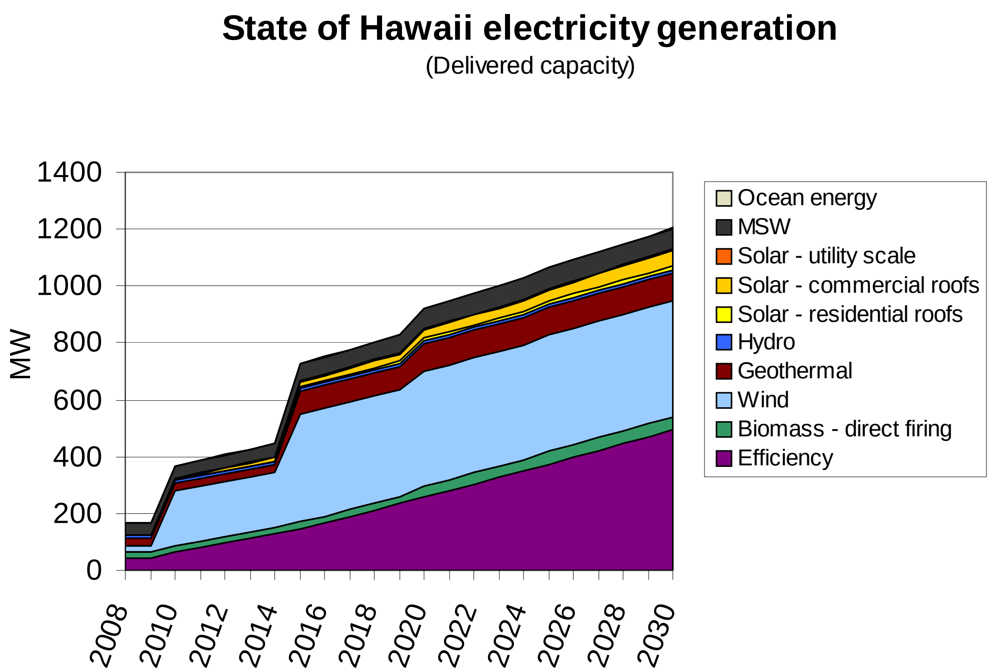
Scenario 5 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation



Summary of 2030 Transportation Results	
Clean energy achieved	***30%***
Oil reduction (million bbl/yr)	***4.7***
CO2 avoided (million ton/yr)	***2.0***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030; biodiesel is imported to meet the RFS
- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

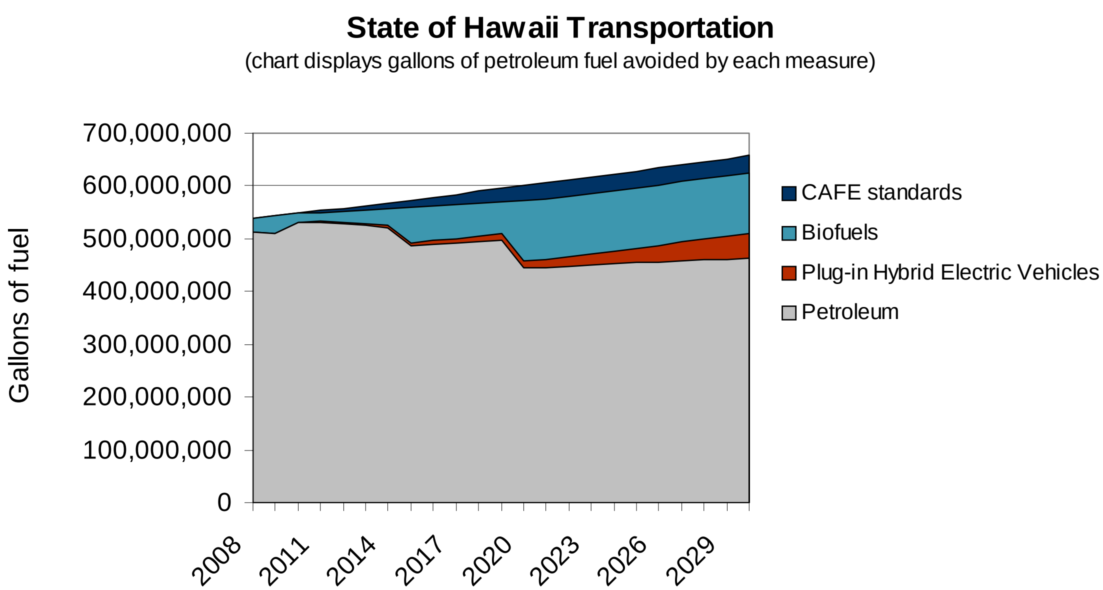
Scenario 6 Electricity - High efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai



Summary of 2030 Electricity Results	
Clean energy achieved	***70%***
Oil reduction (million bbl/yr)	***15.1***
CO2 avoided (million ton/yr)	***7.7***

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (53% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a low penetration level
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (409 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 62 MW statewide in 2030

Scenario 6 Transportation - Low PHEV penetration, maximize ethanol production, all biofuels used for transportation

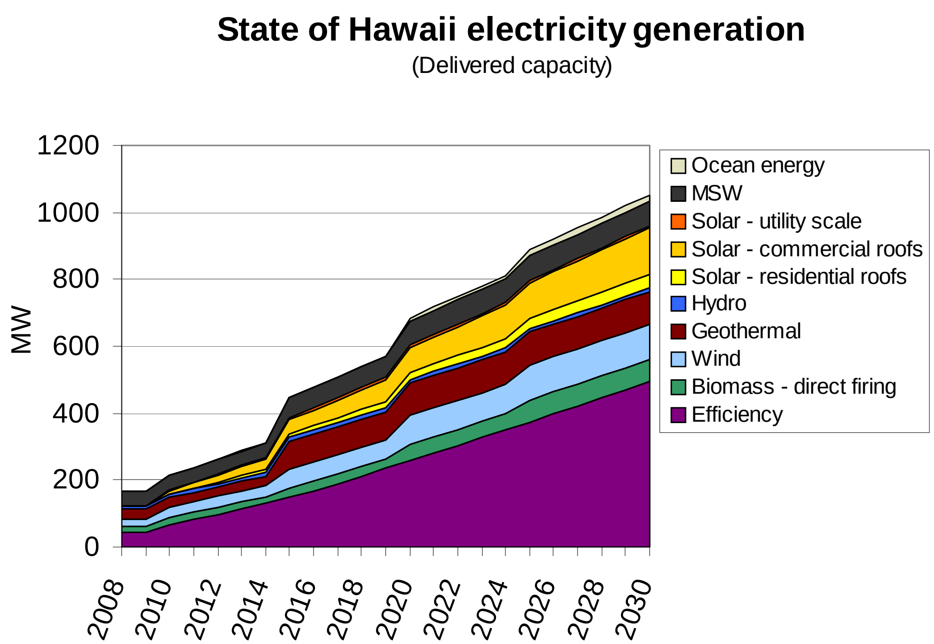


Summary of 2030 Transportation Results	
Clean energy achieved	***30%***
Oil reduction (million bbl/yr)	***4.7***
CO2 avoided (million ton/yr)	***2.0***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a low penetration in 2030 based on an Argonne/EPRI projection (15% of all vehicles sold in 2030 are PHEVs); 50% of technically achievable in-state ethanol is in production by 2020 and is maintained through 2030**;** biodiesel is imported to meet the RFS

- **RESULTS:**
  - Under this scenario, 30% clean energy is achieved primarily through ethanol production
  - Hawaii would have to import an additional 265 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

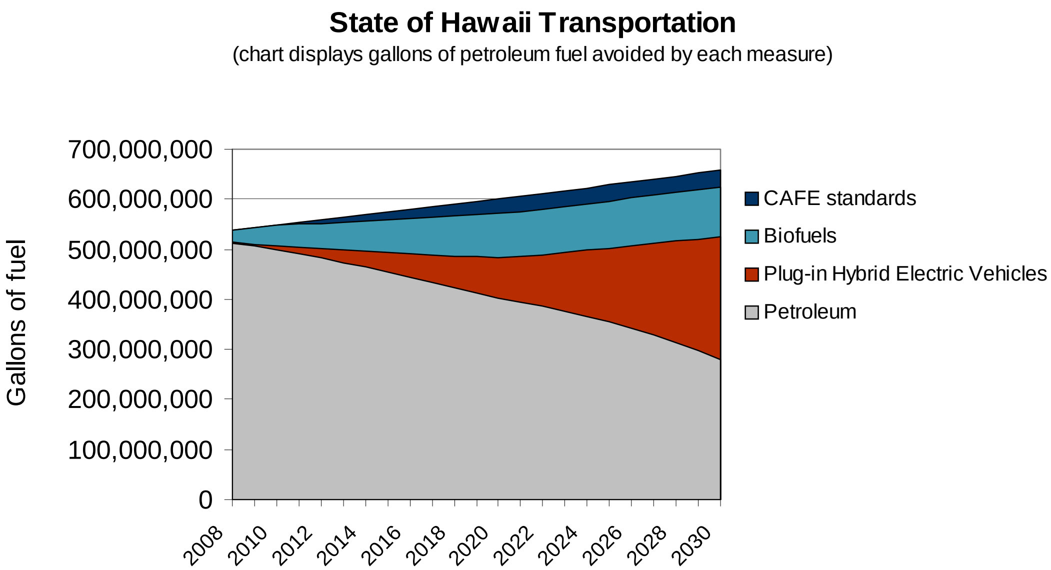
Scenario 7 Electricity - High efficiency, high PHEV penetration with biofuels in electric generation, and no cable



Summary of 2030 Electricity Results	
Clean energy achieved	***57%***
Oil reduction (million bbl/yr)	***14.0***
CO2 avoided (million ton/yr)	***7.2***

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; clean energy of 70% on all islands except Oahu; Oahu clean energy to the maximum allowed by resources (46% without imports); no cable; PHEVs at a high penetration level
  - Oahu would require 220 MGY of biodiesel to reach 70% clean energy for electric generation, but since since only 45 MGY can be produced in-state, the state only reaches 57%
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by rooftop solar (180 MW combined), as well as geothermal and wind. Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

Scenario 7 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



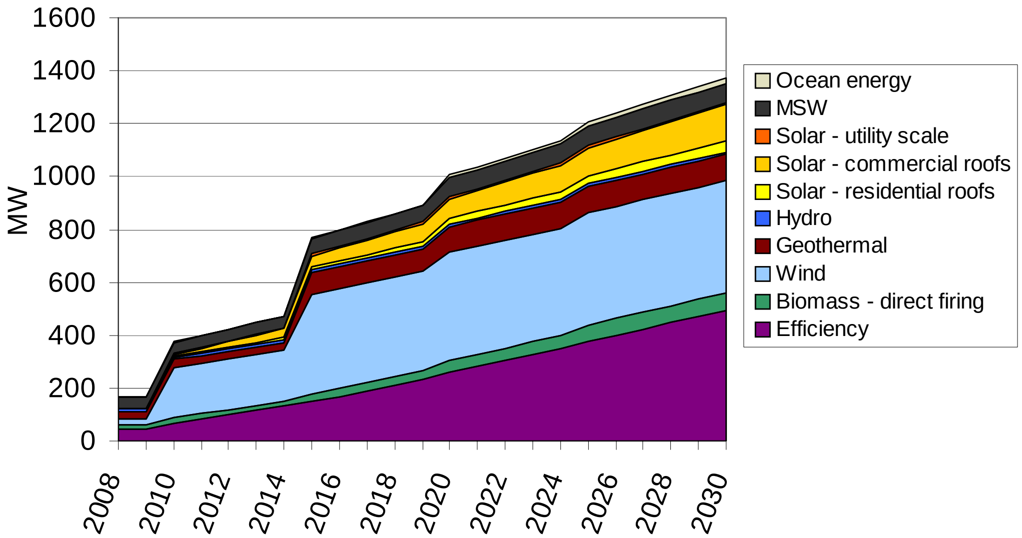
Summary of 2030 Transportation Results	
Clean energy achieved	***57%***
Oil reduction (million bbl/yr)	***9.0***
CO2 avoided (million ton/yr)	***3.8***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to ethanol biodiesel production; biodiesel beyond that required to meet the RFS goes to Oahu generating units to generate electricity

- **RESULTS:**
  - Under this scenario, 57% clean energy is achieved primarily through PHEVs
  - Hawaii would have to import 83 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

Scenario 8 Electricity - High efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai

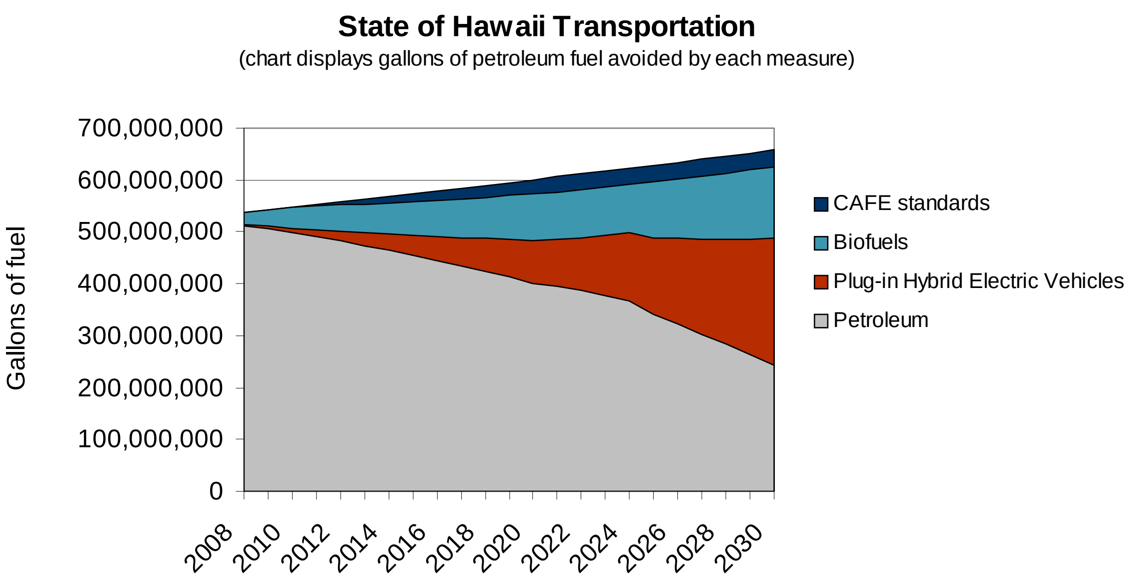
State of Hawaii electricity generation
(Delivered capacity)



Summary of 2030 Electricity Results	
Clean energy achieved	***70%***
Oil reduction (million bbl/yr)	***17.3***
CO2 avoided (million ton/yr)	***8.8***

- **DESCRIPTION:** Energy efficiency to the level of "HCEI high efficiency," which assumes aggressive gains in net zero energy residential buildings and commercial building efficiency; renewable generation of 70% on all islands except Oahu; Oahu renewable generation to the maximum allowed by resources (46% without imports); cable connecting Oahu to Lanai and Molokai; PHEVs at a high penetration level
  - Oahu requires 7 MGY of biodiesel to reach 70% clean energy for electric generation; the remainder of the biodiesel is used for transportation
- **RESULTS:**
  - Energy Efficiency: Under HCEI high efficiency assumptions, demand side management measures would decrease statewide electricity demand by 495 MW (30% of 2030 BAU demand)
  - Electric Generation: Under this scenario, electric generation is dominated by wind (424 MW). Note: These figures represent average electricity delivered, i.e., they have been adjusted for capacity factors
  - Transportation: PHEVs increase total electricity demand by 314 MW statewide in 2030

Scenario 8 Transportation - High PHEV penetration, maximize biodiesel production, biodiesel fills electric generation needs to 70%



Summary of 2030 Transportation Results	
Clean energy achieved	***63%***
Oil reduction (million bbl/yr)	***9.9***
CO2 avoided (million ton/yr)	***4.2***

- **DESCRIPTION:** Plug-in hybrid electric vehicles reach a high penetration in 2030 based on a PNNL projection (69% of all vehicles sold in 2030 are PHEVs); land is dedicated to ethanol in sufficient quantity to meet the RFS with locally grown fuels, with the remaining land going to biodiesel production; biodiesel is not needed in Oahu generating units, so all biofuels are used for transportation

- **RESULTS:**
  - Transportation: Under this scenario, 63% clean energy is achieved primarily through PHEVs
  - Under this scenario, Hawaii would have to import 44 million gallons per year of biofuel (with an energy content equivalent to that of oil) to reach 70% clean energy for transportation in 2030

Next steps for the analysis

- First-order energy delivery and grid upgrade analysis
- Investment analysis and macroeconomic analysis of impacts for the State
- Detailed exploration and costing of a few select scenarios

Appendix

- Assumptions and notes on the analysis
- Island by island summaries for each scenario

Notes on the analysis – electric generation

- Energy demand **baselines** are all taken from utility Integrated Resource Plans (IRPs). Business as usual demand for electricity in 2030 is predicted to grow from the current level of 988 MW to 1,164 MW statewide (This does not include reserve capacity).
- Projected plug-in hybrid electric vehicle (**PHEV**) electricity needs are added onto these numbers
  - In the “Low PHEV” scenarios, PHEVs are 15% of new car sales in 2030 (Argonne/EPRI) and require 62 MW of additional generation capacity
  - In the “High PHEV” scenarios, PHEVs are 69% of new car sales (PNNL) and require 314 MW of additional generation capacity
- Resources were loaded onto each island’s system in the following dispatch order, which reflects the cost ranking – least expensive to most expensive – of each resource according to the California Energy Commission, 2007 (the MSW cost figure comes from the Black & Veatch Renewable Energy Transmission Initiative 2008 report)

Renewable energy cost ranking	
1	Geothermal
3	Wind
4	Biomass
5	Small Hydro
6	Utility scale solar
7	Solar PV
8	Ocean

2: MSW

- Maui geothermal is capped at 30% of its 140 MW capacity (42 MW) as identified in the GeothermEx 2005 and EPACT 355 Reports; the geothermal is used to meet Maui’s demand and is not cabled to Oahu
- Maui has 30% of its 10 MW ocean energy potential (30 MW) deployed in all scenarios because of the planned project
- 50 MW potential is used for Oahu’s ocean energy
- MSW is dispatched to 75% of its potential on all islands. Landfill gas is counted together with MSW
- Development of utility scale solar (concentrated solar power) on Kauai is capped at to 5% of the 285 MW potential identified in the EPACT 355 Report; this and CSP numbers for the other islands were developed in consultation with NREL and state and county energy officials
- Lanai and Molokai demand are not modeled
- The following **capacity factors**, from NREL and EERE, were used for each resource (for wind, 35% was used for Oahu, Hawaii, and Kauai resources, 40% was used for Molokai and Lanai, and 45% was used for Maui)

Capacity factors	
Biomass - direct firing	80%
Wind	35-45%
Geothermal	95.5%
Hydro	44.2%
Solar - residential roofs	22.5%
Solar - commercial roofs	22.5%
Solar - utility scale	24.4%
MSW	95%
Ocean energy	35%

Notes on the analysis – efficiency and transportation

- **Building efficiency** assumptions:
  - 55% of all existing housing stock will be retrofitted by 2030
  - 1% of building stock each year is demolished and replaced with new construction
  - Max efficiency potential for all residential buildings is 50% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for new commercial buildings is 53% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for existing commercial buildings is 42% better than ASHRAE 90.1.2004 standard
  - Max efficiency potential for all new/retrofitted buildings will be reached in the year 2015, and remain constant until 2030
  - Current efficiency potential is 36% for residential new construction, 34% for residential retrofits, 30% for commercial new construction, and 19% for commercial retrofits

- The transportation model assumes that 50% of the potential identified in the 2006 ethanol study by HNEI is actually available for **ethanol** and that 50% of the potential identified in the HARC biodiesel study is actually available for **biodiesel**; the rest of the land is assumed to be dedicated to food production or some other use
  - This would result in about 142,000 acres devoted to crops for ethanol under the max ethanol scenario (Scenarios 1,2,5 and 6) and 124,000 acres devoted to biodiesel under the max biodiesel scenario (Scenarios 3,4,7 and 8). It is assumed that there is a high degree of overlap between these two land areas
  - These acres are <u>either</u> in ethanol or biodiesel production. In scenarios 1,2,5, and 6, ethanol is produced to the exclusion of biodiesel. All ethanol is used only in the transportation sector. Biodiesel is imported to meet the RFS; this cost is included in the cost model
  - In scenarios 3, 4, and 7, biodiesel is produced to the exclusion of ethanol. In these scenarios, biodiesel beyond that required to meet the RFS is provided to the generation sector. Ethanol is imported to meet the RFS; the cost thereof is included in the cost model
  - In Scenario 8, biodiesel is produced to meet the RFS and ethanol is imported. The generation model shows that by the year 2030, only a small quantity of biodiesel (7 million gallons) will be required to achieve 70% clean energy in the electricity sector. This quantity of biodiesel is given to the generation sector and the remainder is used in the transportation sector
  - There are no scenarios under which both ethanol and biodiesel are produced in sufficient volumes to meet the RFS

Resource potential for all Hawaii islands – units are potential of installed capacity

	Source		Oahu	Kauai	Maui	Hawaii	Lanai	Molokai	Total
Biomass	355 Report /1	MW	7	20	8	20	no data	6	
	KIUC Renewable Energy Technology Assessment			20					
	Hawaii Energy Strategy 2000/2	MW	25	25	25	50			
	Value used for BAH model		25	25	25	50	0	0	**125**
Wind	355 Report	MW	At least 50	At least 40	At least 40	At least 10	no data	no data	
	Proposed projects/3	MW			97		400	400	
	Hawaii Energy Strategy 2000	MW	65			85			
	Value used for BAH model		65	40	97	85	400	400	**1087**
Geothermal	355 Report (from GeothermEx 2005)	MW	n/a	n/a	140	750	n/a	n/a	
	Value used for BAH model		0	0	140	750	0	0	**890**
Hydro	355 Report	MW	no data	no data	3	20	20	no data	
	KIUC RETA	MW		21					
	Hawaii Energy Strategy 2000	MW		7					
	Value used for BAH model		0	21	3	20	0	0	**44**
Solar - rooftop	Residential roof analysis /5	MW	416	35	80	94			
	Commercial roof analysis /6	MW	576	48	111	130			
	Value used for BAH model		992	83	191	224	0	0	**1490**
Solar - utility scale	NREL estimate	MW	8	8	8	8			
	355 Report			285					
	Value used for BAH model		8	14	8	8	0	0	**37**
MSW (incl. landfill gas)	Hawaii Energy Strategy 2000	MW		25					
	KIUC RETA / County energy staff	MW	57	8	8	10			
	Existing plant (H-POWER)	MW	46						
	Value used for BAH model		57	8	8	10	0	0	**83**
Ocean energy	Estimates / proposed projects		50		10				
	Value used for BAH model	MW	50		10				**60**
Total	*Value used for BAH model*	**MW**	**1196**	**192**	**481**	**1147**	**400**	**400**	**3816**

1. "Assessment of Dependence of State of Hawaii on Oil" for EPACT Section 355, DOE, 2007.

2. Hawaii Energy Strategy 2000. Prepared by DBEDT

3. Lanai: DBEDT website--Castle and Cooke is investigating a 300 MW wind farm on Lanai; Molokai: Hawaii Star Bulletin, "Wind Power Firm Vows $50M for Molokai Bid."

Maui: DBEDT wesbite: http://hawaii.gov/dbedt/info/energy/renewable/wind

5. NREL estimates 2.5 kW per house, assume that half of Hawaii's 500,036 houses (as of 2006 census) are suitable for PV on the roof

6. In 2003, Hawaii had approx. 173 mil sq feet of commercial buildings, according to HECO (http://hawaii.gov/dbedt/ert/rebuild/minutes/May03Presentations/Benchmarking.pdf), 100 sq ft per kW (which is the figure for the 309 kW, 31,000 sq ft Ford Island array), assume that commercial buildings are proportional to residential buildings on each island to get island by island estimate, then assume that half of Hawaii's commercial buildings are suitable for solar

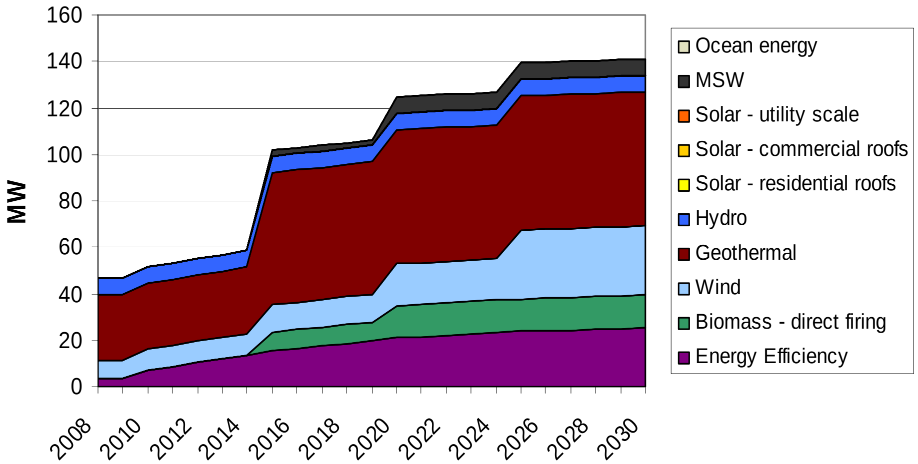
Note: Proposed projects, existing plants, KIUC RETA, HES 2000, and county energy staff estimates are used if they are greater than those listed in 355 Report

Sources

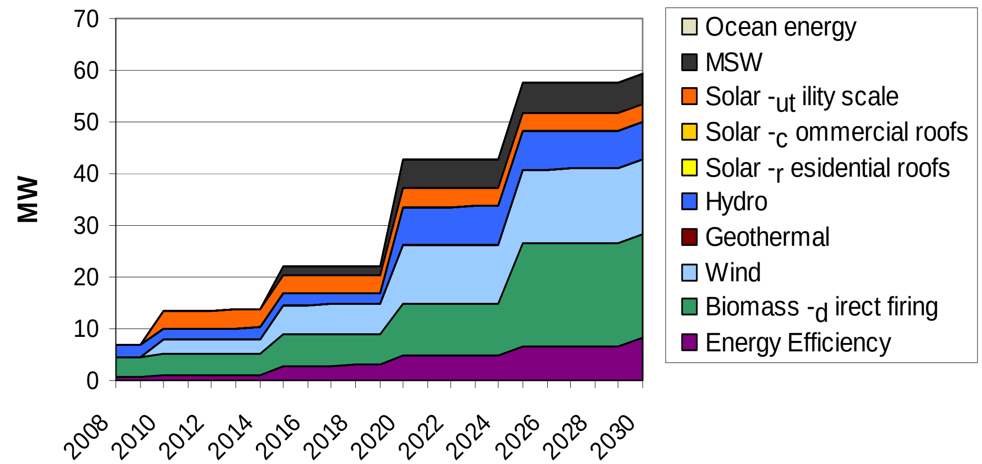
- Utility IRPs (HECO, MECO, HELCO, KIUC)
- NREL, EIA, Pacific Northwest National Lab, Argonne National Lab, EPRI
- California Energy Commission and California Solar Resources Report
- Black & Veatch Renewable Energy Transmission Initiative
- 355 Report: Assessment of Dependence of State of Hawaii on Oil
- KIUC Renewable Energy Technology Assessment
- Catalog of Potential Sites for Renewable Energy in Hawaii
- HARC Biodiesel Crop Implementation for Hawaii
- HNEI Potential for Ethanol Production in Hawaii
- Hawaii Energy Strategy 2000
- Hawaii Databook

Scenario 1 Electricity - Moderate efficiency, low PHEV penetration, and no cable connecting the islands

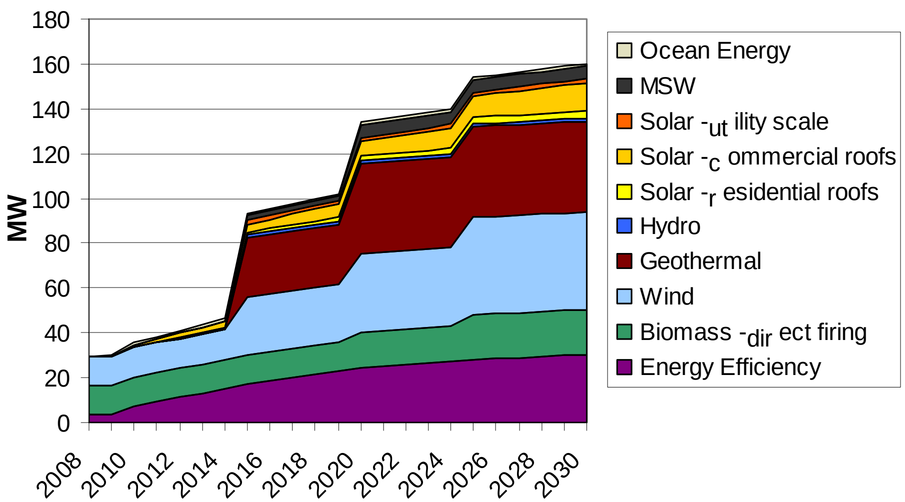
Hawaii



Kauai



Maui



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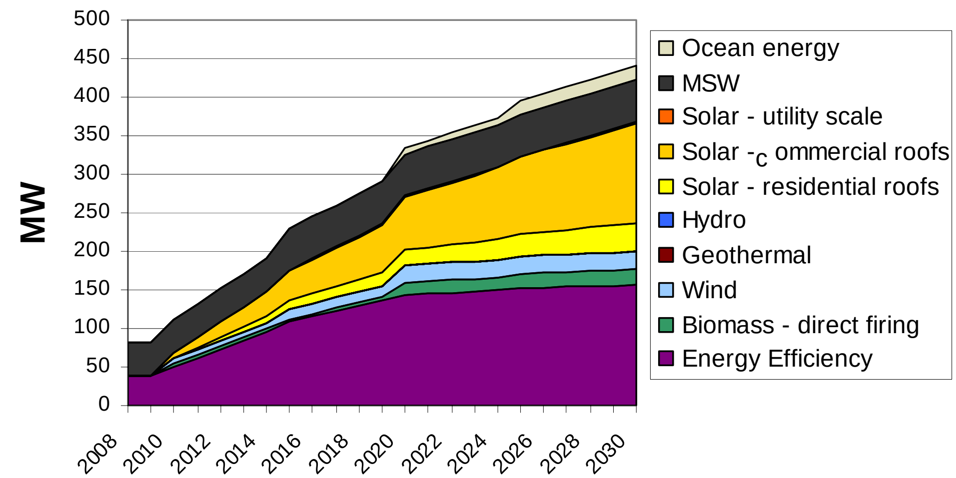

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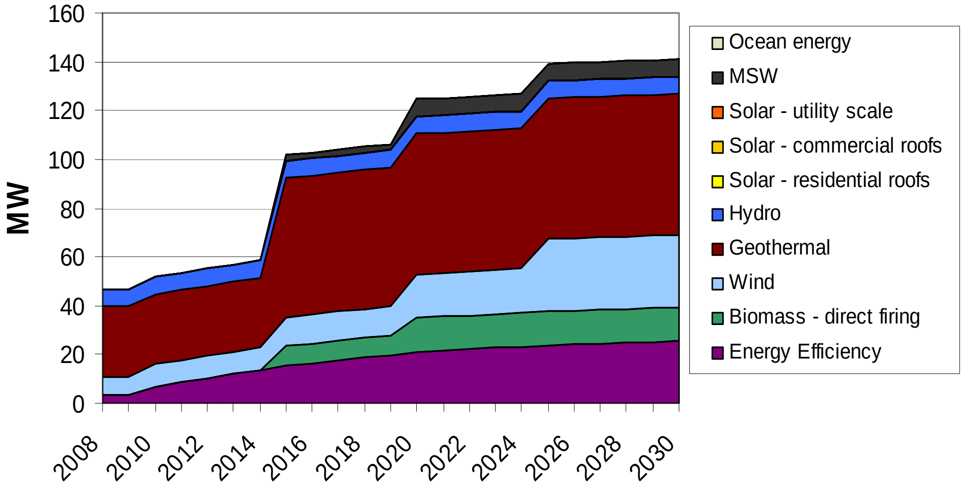
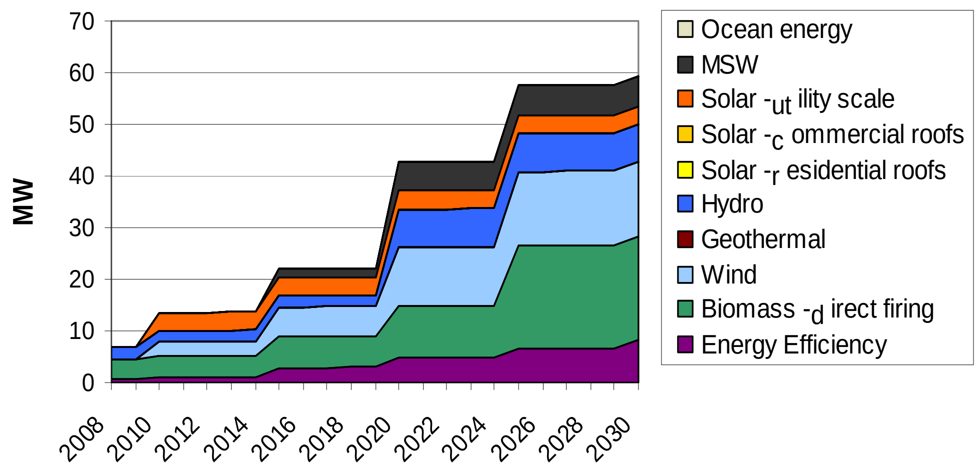
Scenario 2 Electricity - Moderate efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai

Hawaii



Kauai



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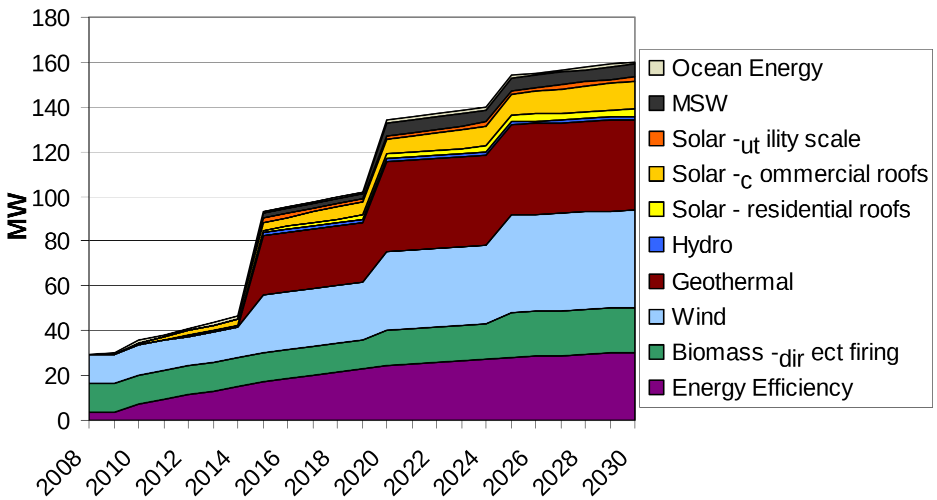
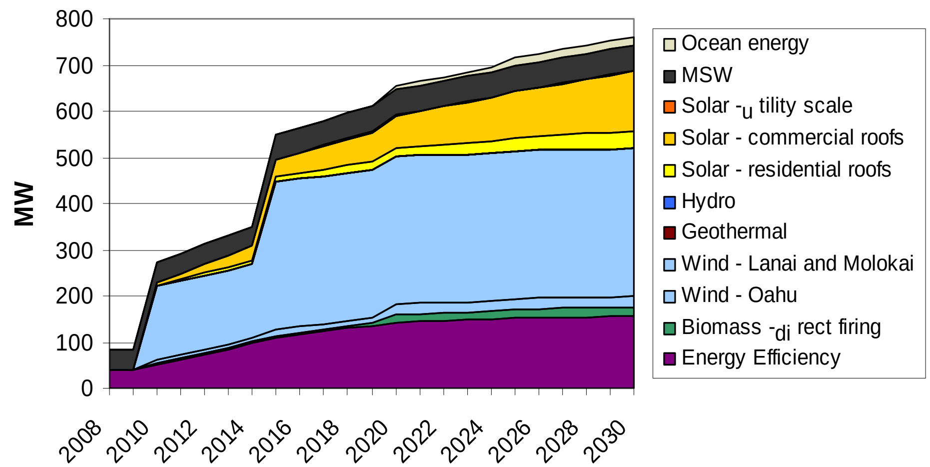


Oahu



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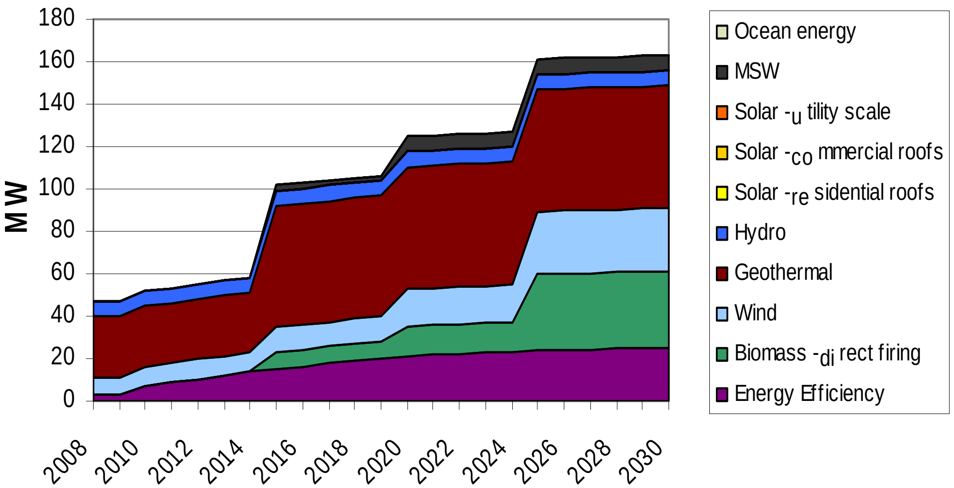
Scenario 3 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and no cable

Hawaii



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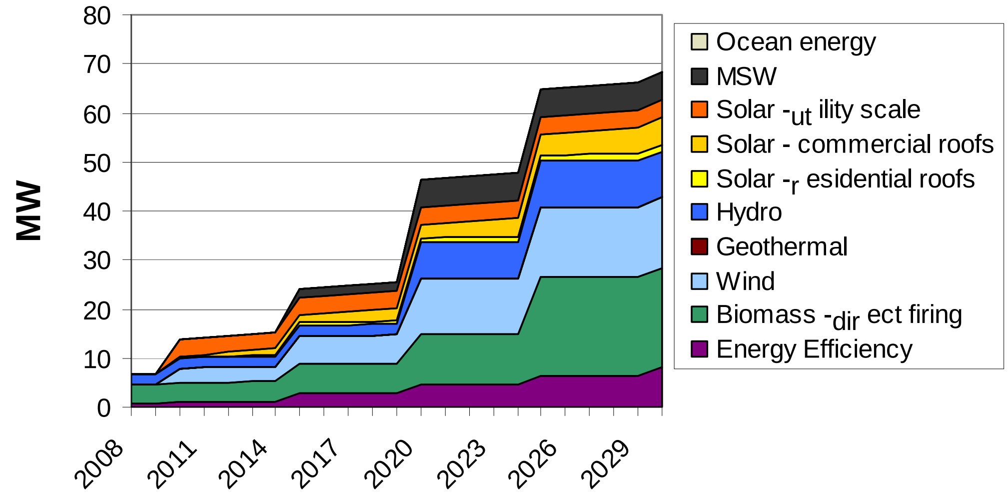

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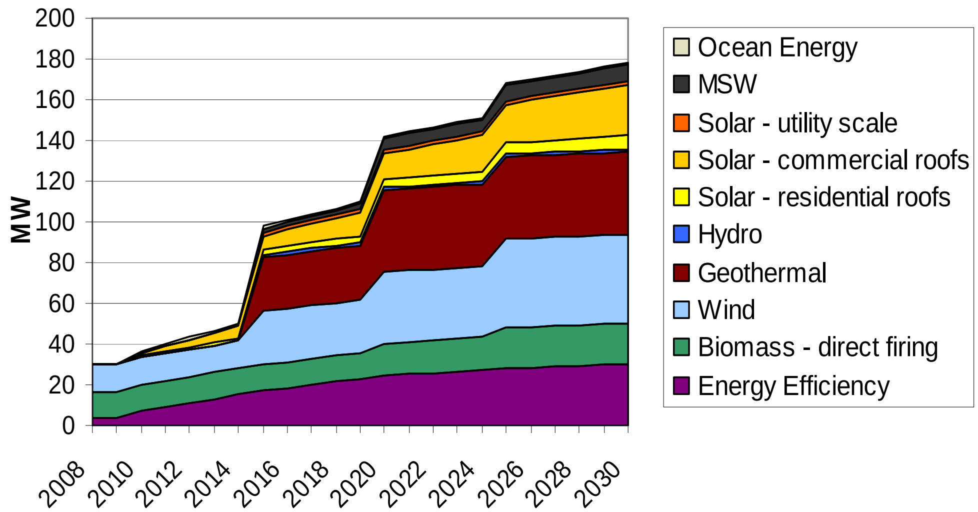

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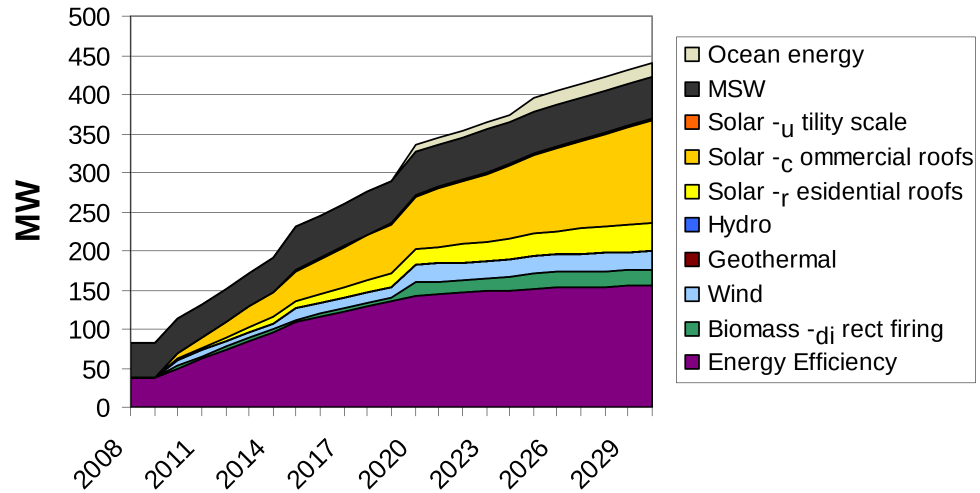

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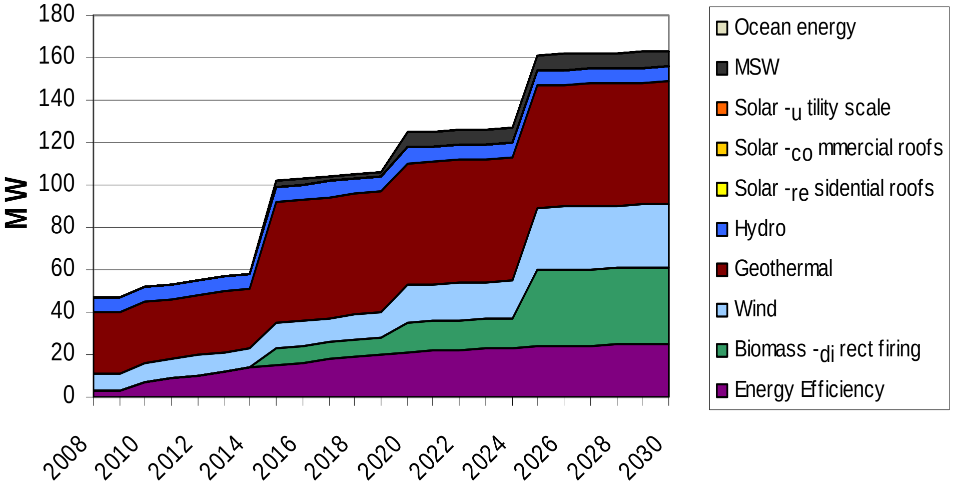
Scenario 4 Electricity - Moderate efficiency, high PHEV penetration with biofuels in electric generation, and a cable to Oahu from Lanai and Molokai

Hawaii



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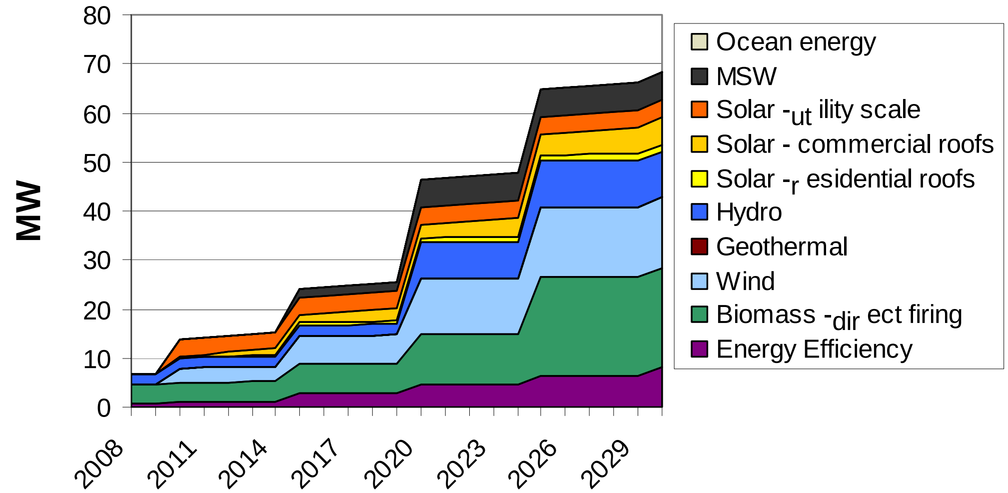

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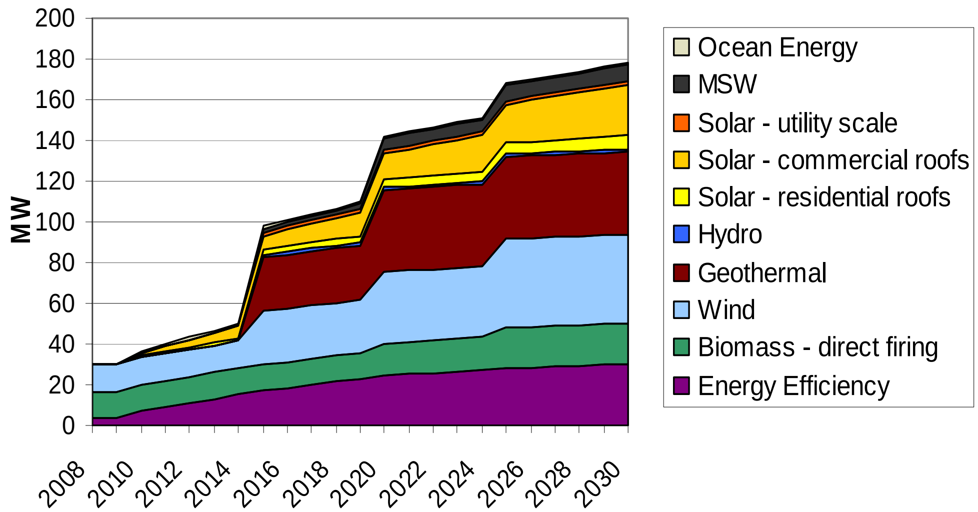

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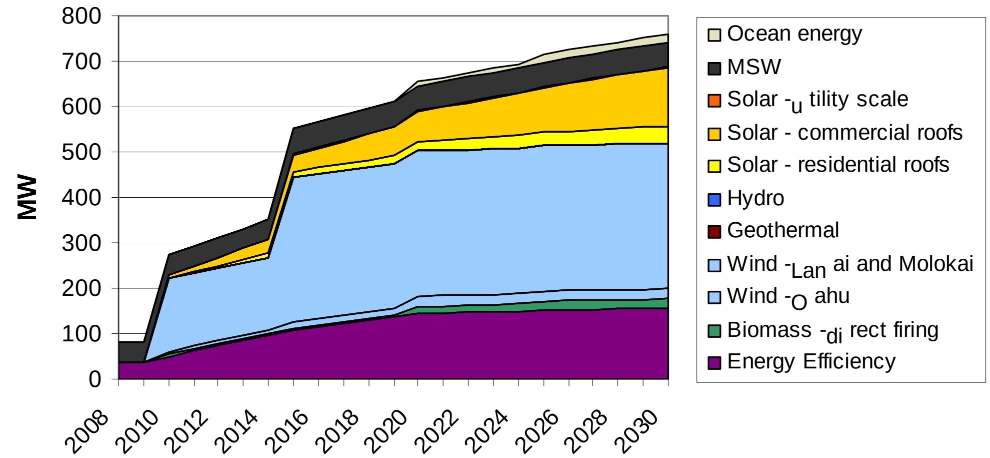
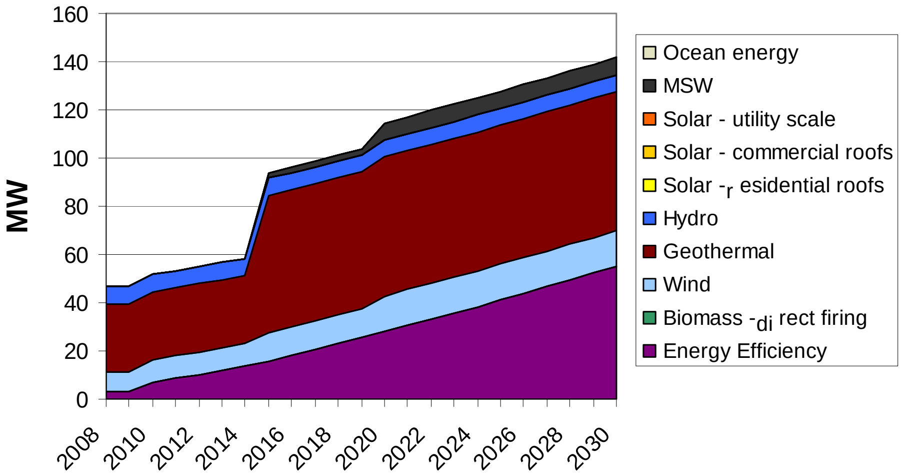


Scenario 5 Electricity - High efficiency, low PHEV penetration, and no cable connecting the islands

Hawaii



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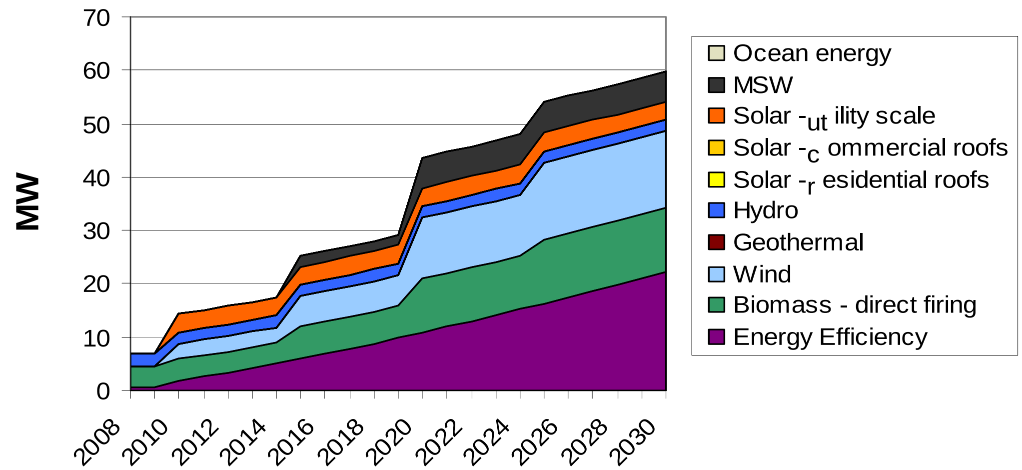

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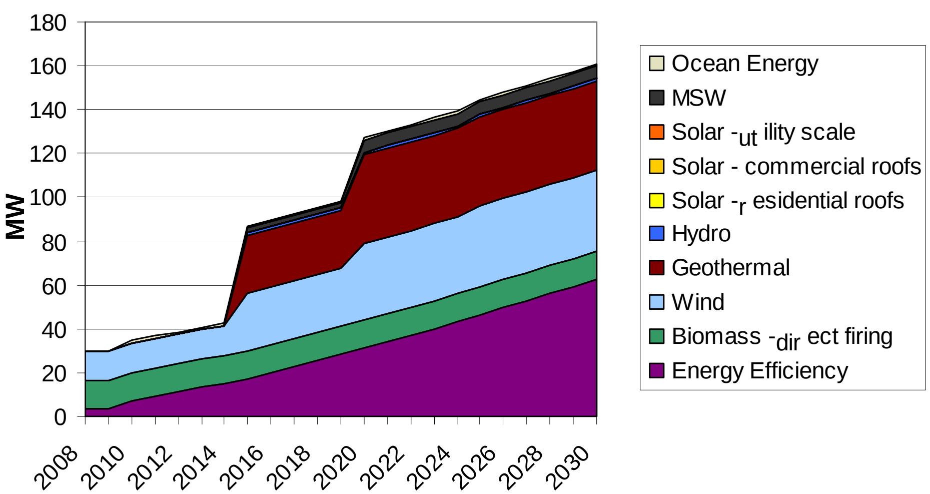
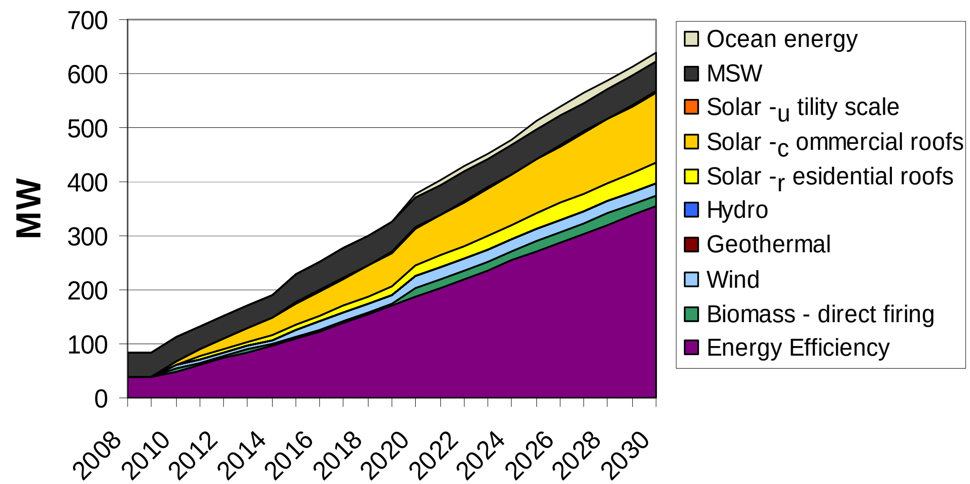


Oahu



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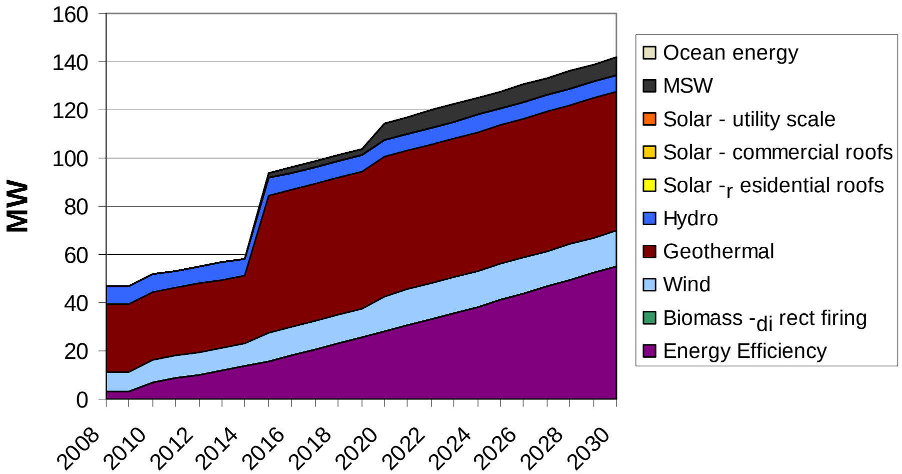
Scenario 6 Electricity - High efficiency, low PHEV penetration, and a cable to Oahu from Lanai and Molokai

Hawaii



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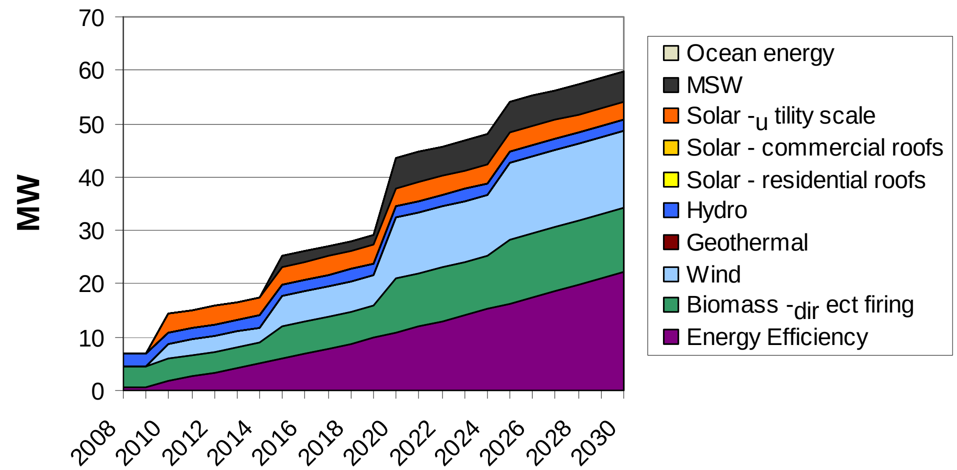

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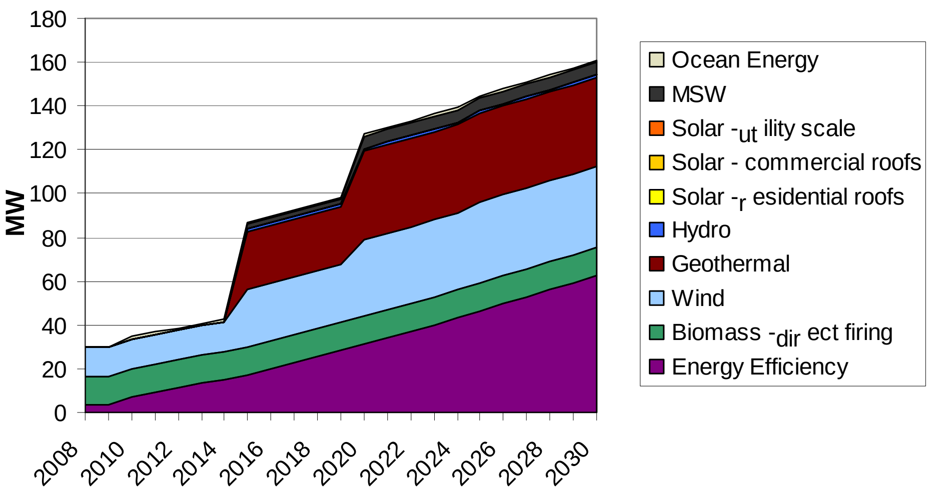
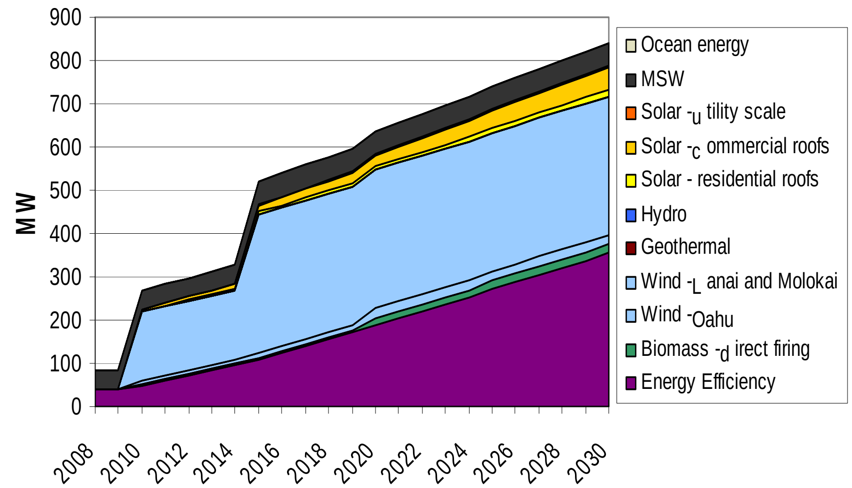


Oahu



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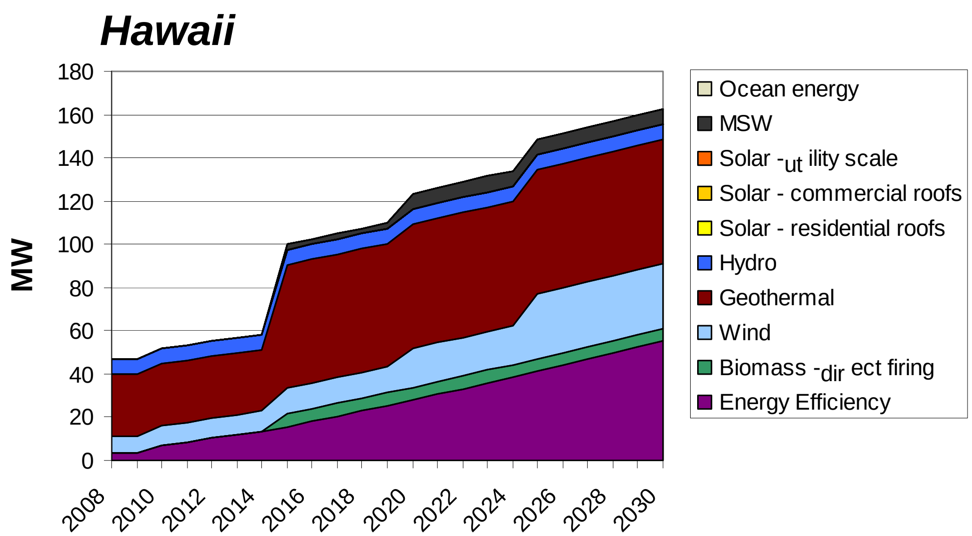
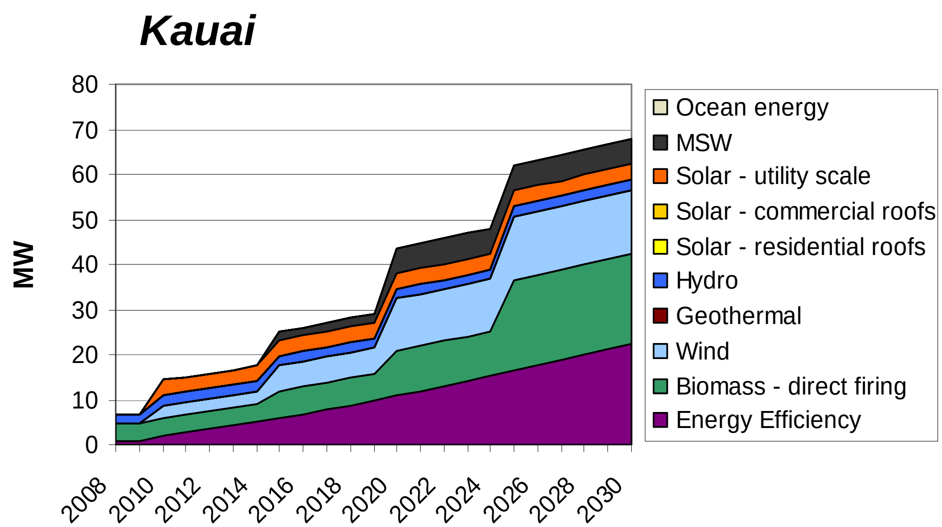
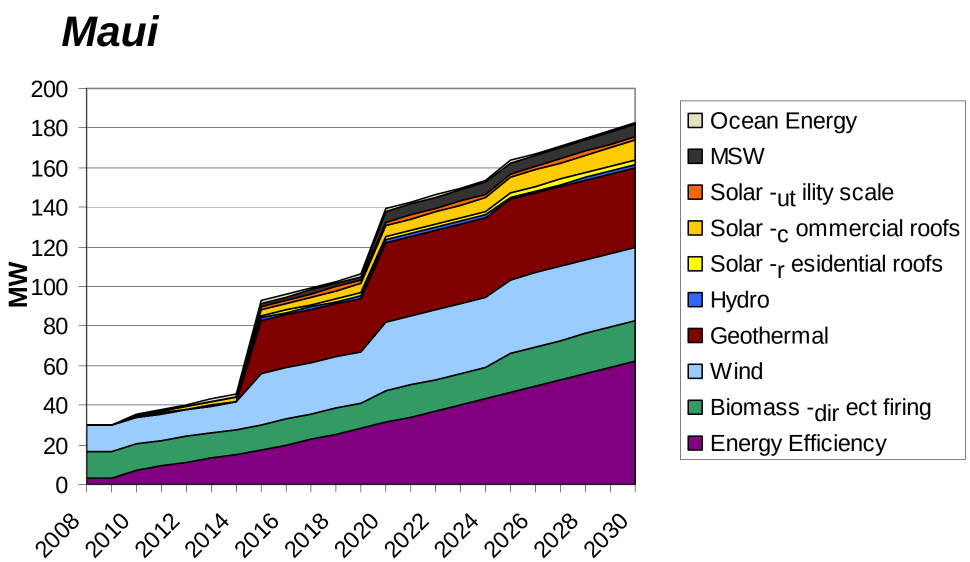
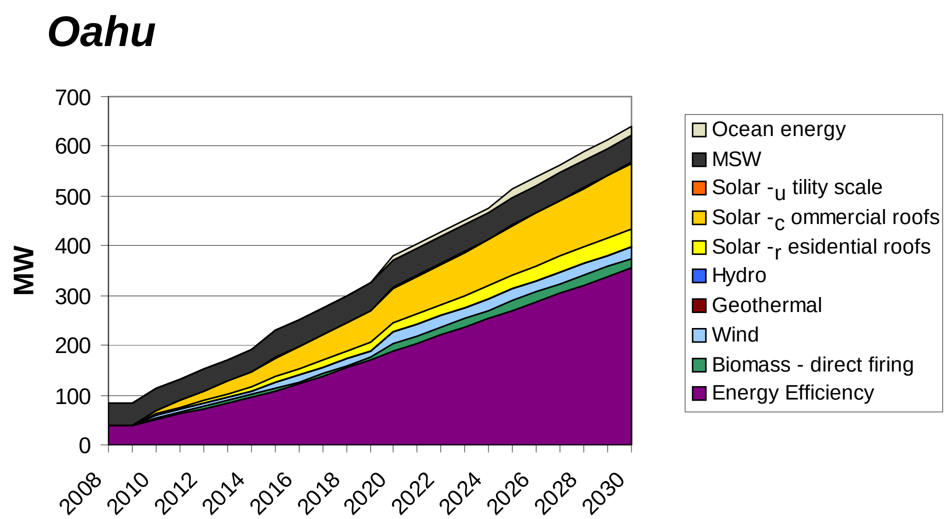
Scenario 7 Electricity - High efficiency, high PHEV penetration with biofuels in electric generation, and no cable









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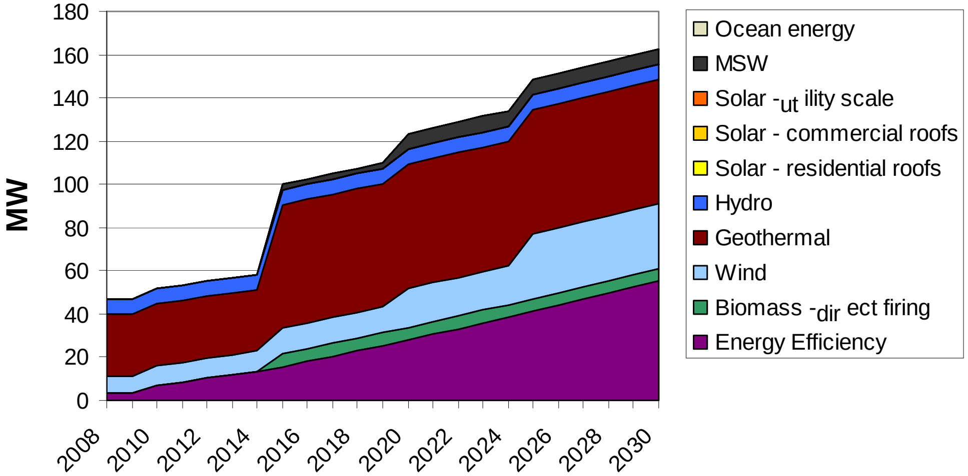
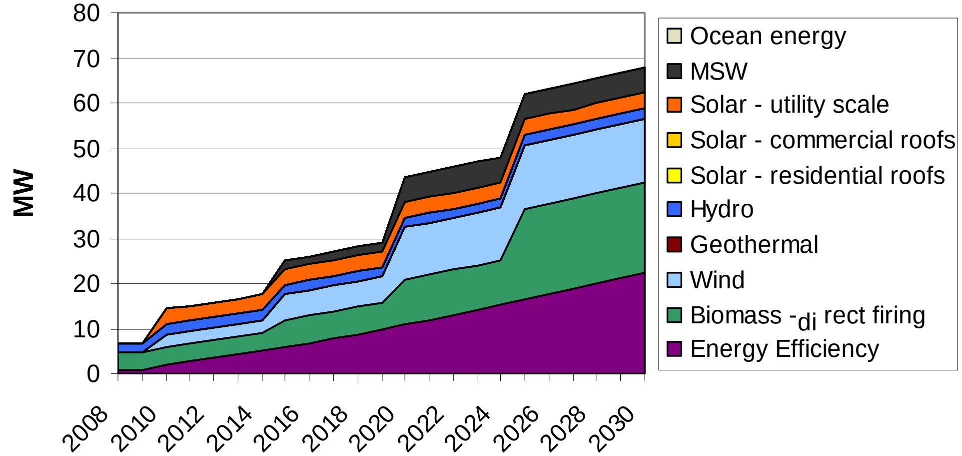
Scenario 8 Electricity - High efficiency, high PHEV penetration, and a cable to Oahu from Lanai and Molokai

Hawaii



Kauai



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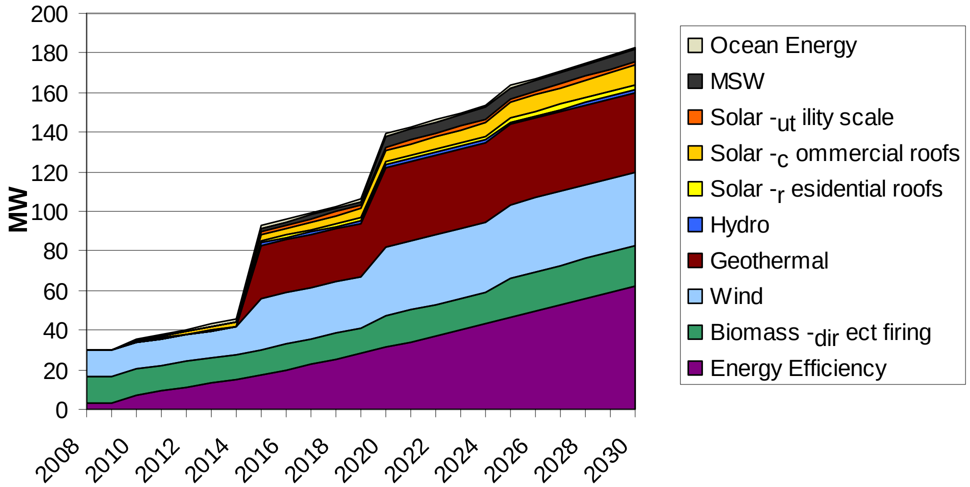

Oahu