# Hawaiʻi Natural Energy Institute Research Highlights

*Energy Policy & Analysis*

***AES Biomass Conversion***

**OBJECTIVE AND SIGNIFICANCE**: The Oʻahu coal plant operator, AES Hawaiʻi, has put forward a proposal to the Hawaiʻi Public Utilities Commission (PUC), HECO, and the Hawaiʻi State Energy Office (HSEO) to convert the plant to biomass sourced from North America. During initial community discussions of this possible conversion, concerns were raised regarding its cost, impact on future solar development, and need for such a plant on the Oʻahu grid. Following these discussions, HNEI undertook a study to better characterize the potential and the impacts of such a conversion. The objective was to provide unbiased information about the conversion and, if warranted, to facilitate additional discussions within the community.

**KEY RESULTS**: HNEI's analysis of the conversion of the AES coal plant to use biomass addressed several issues including:

- **RPS/Energy**: potential for significant contribution to the state's RPS goals without need for new transmission infrastructure.
- **Impact on Future Solar Development**: generation using biomass would not impact the ability to utilize additional solar energy
- **Resource Adequacy/Capacity**: firm generation would provide capacity reliability while enabling additional fossil retirement
- **Cost**: cost of the biomass energy can be comparable to fossil fuel. Avoided costs for fossil fleet operations and maintenance also need to be considered.
- **Emissions**: detailed life-cycle analysis required to assess net avoided $CO_2$ emissions

While electricity produced by the converted AES Biomass plant would be at a higher cost than recent hybrid solar and storage resources, the expected energy cost is sufficiently competitive with current fossil generation to warrant more detailed studies. Additionally, it was found that the plant could provide a large contribution (up to 20%) towards the state's renewable portfolio standard (RPS) while also providing firm capacity for Hawaiʻi's energy transition. Significantly, conversion of the AES coal plant was found to not limit further solar development across the island. Specifically, it was found that all of Stage 1 and Stage 2 plus another allotment of solar, larger than Stage 1 and Stage 2 could be accommodated without any significant curtailment.

To put this RPS contribution in perspective, energy from the AES Biomass plant would be roughly equivalent to that from 650 MW of utility-scale solar PV, more than all the utility-scale PV installed on Oʻahu after Stage 1 and Stage 2 is complete. Similarly, it would equate to more than double the amount of rooftop PV installed over the past ten years, equal approximately to having solar on every single-family home on Oʻahu.

While conversion to biomass would result in a substantial reduction of GHG emissions from fossil sources, a detailed assessment of the proposed biomass sources would be needed to quantify actual savings. This was beyond the scope of this initial study.

**BACKGROUND**: The AES coal plant is Oʻahu's largest generator and currently represents 15-20% of the utility's annual generation. The plant's retirement, scheduled for September 2022, will decrease the amount of dispatchable thermal capacity available to the utility by more than 10%. The retirement of the coal plant will end the use of coal for electricity generation in Hawaiʻi. To make this transition permanent, Hawaiʻi 2020 Act 23, Senate Bill 2629, prohibits new or renewed power purchase agreements for electricity generated from coal and prohibits the issuance of air permits for coal burning power plants on December 31, 2022.[1]

HECO is currently procuring a portfolio of hybrid solar + storage sources, as well as standalone storage to replace the coal plant's capacity and energy. These resources were procured via the utility's competitive bidding framework and are collectively referred to as the Stage 1 and Stage 2 projects. While many of the solar and storage resources were proposed to be available prior to the AES coal plant retirement, delays in the development, PPA negotiations, interconnection studies, and recent supply shortages have pushed out the commercial online dates of the replacement resources until after the coal plant

[1] Hawaiʻi State Legislature, SB2629 SD2 HD1, https://www.capitol.hawaii.gov/Archives/measure_indiv_Archives.aspx?billtype=SB&billnumber=2629&year=2020

retirement and PPA expiration. The impact of the AES retirement on resource capacity on O‘ahu is the subject of another study conducted by HNEI and included in this report.

To facilitate discussions and data collection the PUC opened a proceeding to review the status of AES retirement and the interconnection of replacement resources.[2]

As a result of this proceeding, the HSEO created the Powering Past Coal Task Force to "convene stakeholders to increase transparency, coordination, collaboration, and urgency to timely facilitate, coordinate, and align project development and reviews by Hawaiian Electric, state, and county agencies for those measures anticipated to provide electricity for O‘ahu to replace the coal plant's electricity…"[3] One option that was considered by the Task Force was a conversion of the AES plant to operate with a biomass fuel source. At the request of the Task Force chair, AES Hawai‘i, LLC put forward a proposal to continue the use of coal at AES through the remaining three months of 2022 to provide grid reliability and then convert to biomass operations in 2023.[4]

According to AES Hawai‘i, "Depending on the length of time biomass would be expected to be used, AES could consider different conversion options and different power purchase agreement ("PPA") terms. We expect such a biomass project could support O‘ahu's needs for a successful energy transition, and at a lower cost to consumers. Our current all-in cost estimates to operate on biomass are between approximately 0.18-0.20 cents/kWh, subject to additional engineering work, update in equipment pricing, availability and cost of biomass pellets, permitting costs and timeline, and the expected capacity factor, as well as the Commission-approved PPA terms between Hawaiian Electric and AES."

**PROJECT STATUS/RESULTS**: To better understand the role of biomass and the AES conversion in O‘ahu's future energy mix, the HNEI team conducted a cost-benefit feasibility analysis of the proposed conversion. This analysis included hourly PLEXOS production cost simulations comparing cases with and without the AES Biomass conversion. Production cost models simulate grid operations on an hour-by-hour (or sub-hourly) basis across an entire year. The simulations included detailed operating characteristics of the generation mix, fuel prices, wind and solar resource availability, hourly load, and transmission constraints. A series of cases were evaluated across a wide range of potential AES operations (from 2% to 90% annual capacity factors). The cases with and without the AES conversion were then compared to quantify RPS contribution, assess the impact on future solar development and curtailment, evaluate its contribution to resource adequacy (grid reliability), identify costs or cost benefits, and quantify emissions saved from the avoided fossil fuel.

In order to quantify the costs and benefits of the AES Biomass conversion across range of future system conditions, two scenarios of grid operations were evaluated. A resource mix consistent with the IGP 2024 plans which included all the approved Stage 1 and Stage 2 solar and storage resources under development, as well as HECO's forecast of continued distributed energy resource additions was evaluated. Fuel and load assumptions from HECO's IGP forecast were also included.

A second analysis was also conducted to evaluate the impacts of the AES conversion with a larger solar resource mix. For this study, HNEI used assumptions for 2030 but also assumed an additional "Stage 3" tranche of 400 MW of utility solar with1600 MWh of storage plus an additional 100MW of DER growth (relative to 2024).

Fuel prices were held constant between the two simulations to allow for direct comparisons, and fuel price sensitivities were conducted separately to identify costs across a range of potential oil prices. Lastly, both sets of runs assumed the proposed retirement of Waiau units 3-6, with additional

[2] Hawai‘i Public Utilities Commission, "Opening a Proceeding to Review Hawaiian Electric's Interconnection Process and Transition Plans for Retirement of Fossil Fuel Power Plants," Docket No, 2021-0024.
[3] Hawai‘i State Energy Office, "Power Past Coal Task Force," https://energy.hawaii.gov/ppctf
[4] AES Hawai‘i, LLC, "Letter from J. Bigalbal to the Hawai‘i Public Utilities Commission," Dated June 16, 2021, Docket No. 2021-0024, https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21F17A84517B00533

retirements evaluated in the resource adequacy analysis. The primary tool used in these analyses was PLEXOS, a commercially available production cost model. The reliability analysis also used PLEXOS, but in a stochastic manner that was described in last year's report.

**PS/Energy: biomass conversion could provide a large contribution towards the state's RPS**

Results of the production cost analysis indicate that AES Biomass could operate across a wide range of potential use cases, operating as a reliability-only asset (2% capacity factor) up to full energy output (90% capacity factor). In these cases, shown in Figure 1 below, nearly all displaced generation occurs on HECO's steam oil fleet, namely the Kahe units 1-6 and Waiau units 7-8 reducing both fuel costs and fossil emissions. The Waiau 7 and 8 units were used sparingly with the AES conversion, indicating that both units are candidates for future retirement and thus were evaluated in subsequent resource adequacy analysis.

The RPS benefits assume that the biomass meets the state's definition of renewable energy, is sustainably sourced, and meets low carbon life-cycle requirements. The AES plant operating on biomass could produce up to 1,500 GWh of electricity per year. This represents approximately 20% of the island's sales and RPS requirement, after reducing for behind the meter PV and transmission losses. The RPS contribution across a wide range of capacity factors, and in both the 2024 and 2030 resource mixes is shown in Figure 2. To put this RPS contribution in perspective, energy from the AES Biomass plant would be roughly equivalent to that from 650 MW of utility-scale solar PV, more than all the utility-scale PV installed on Oʻahu after Stage 1 and Stage 2 is complete. Similarly, it would equate to more than double the amount of rooftop PV installed over the past ten years, equal approximately to having solar on every single-family home on Oʻahu.

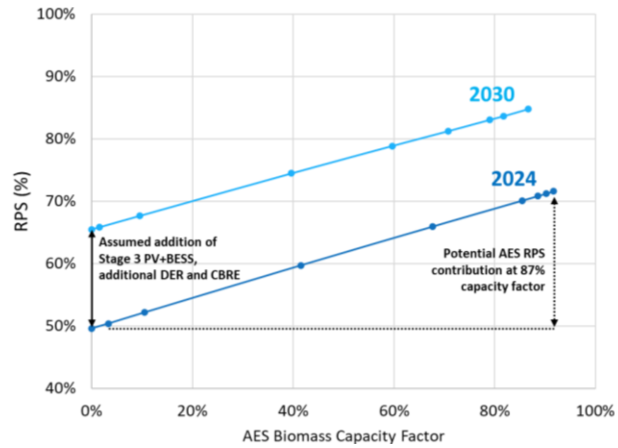


Figure 2. RPS Contribution of AES Biomass in 2024 and 2030.

Significantly, this gain toward achieving the state's RPS goals would not require new transmission infrastructure. The plant is situated in the Campbell Industrial Park, with multiple 138 kV high-voltage paths interconnecting to load centers in Honolulu. The transmission infrastructure on the leeward side of the island was designed to transfer power from two-thirds of the island's thermal capacity (AES, Kalaeloa CC, CIP CT, and Kahe plants) so there is adequate transfer capability. In addition, this region of the island does not have many suitable sites for solar PV development, so use of the existing transmission

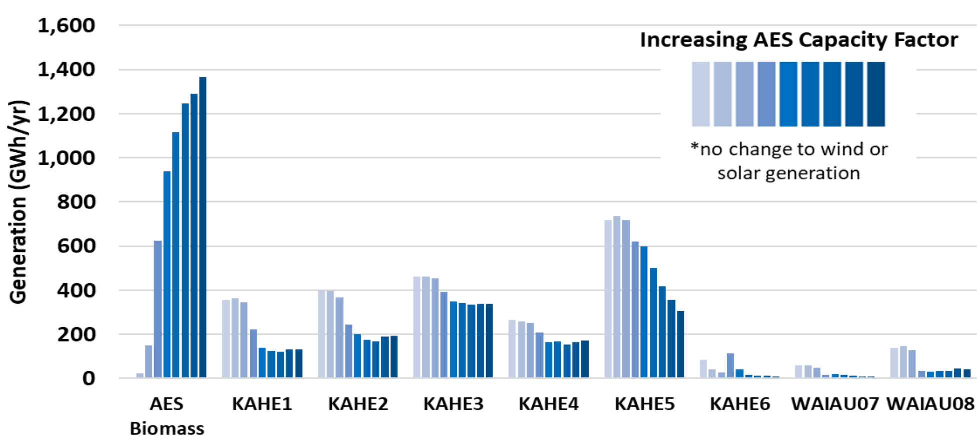


Figure 1. Generation by AES Relative to Steam Oil Displacement.

infrastructure would not conflict with future solar development needs.

**Impact of Future Solar Development: AES Biomass would not impact future solar development**

The production cost analysis used to quantify unit operations for the two solar scenarios, with and without biomass, also provide detailed information on the utilization of the deployed solar systems. Most notably, under neither of these scenarios was there an increase in curtailment of wind or solar resources. This indicates that even at high output, the conversion of AES to biomass would not interfere with ongoing plans by the utility, developers, and stakeholders to economically interconnect new solar PV resources to the grid. In the cases with the highest AES utilization, there was a modest increase in battery cycling, indicating that solar was put through battery storage systems to be utilized later in the evening hours rather than going directly onto the grid in the middle of the day.

**Resource Adequacy: biomass conversion would provide capacity reliability and resource adequacy**

As discussed above, the original genesis of the AES Biomass conversion proposal was based on a plan to continue coal operations through 2022 to help meet reliability needs until adequate Stage 1 and Stage 2 solar and storage projects come online.

In this work, the HNEI-Telos Energy team examined reliability and resource adequacy benefits in a future context, longer term operation on biomass to support reliability and possibly the retirement of additional steam oil units.

To evaluate the resource adequacy contribution of the AES Biomass plant, a resource mix that included all of Stage 1 and Stage 2 plus an additional Stage 3 (400 MW of PV+BESS resources) was evaluated with incremental retirements of thermal generation. Each case was evaluated across 504 randomly generated samples that evaluated various weather years and thermal generator outages. The analysis quantified the number of times when the system did not have sufficient capacity available to serve load (referred to as a loss of load event).

Figure 3 shows the loss of load expectation (LOLE days/year), with and without conversion of the AES plant, for various retirement scenarios including Waiau 3-8 and Kahe 1-2). The analysis shows that full solar deployment of Stages 1-3 and the operation of AES allows for the full retirement of the Waiau plant, and one additional steam oil unit. Without AES, the retirement of just the Waiau plant puts reliability near the historical reliability criterion of 0.22 days/year. The addition of the 180 MW biomass plant enables a retirement of 140-160 MW of aging steam oil capacity beyond that without AES.

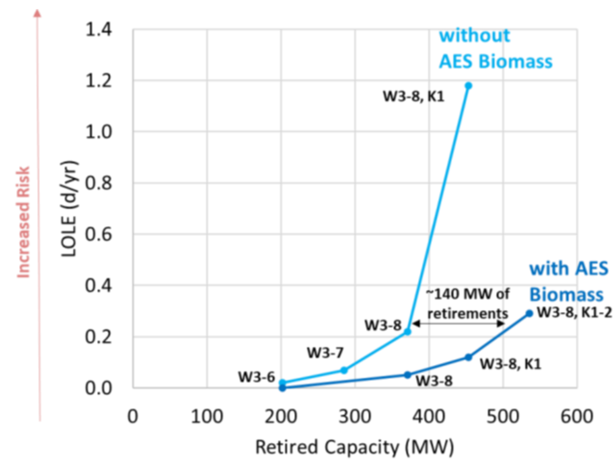


Figure 3. Reliability Risk with and without the AES Conversion.

The biomass plant does not provide a full one-to-one replacement of steam oil units due to the larger size of the AES unit. However, this analysis made the conservative assumption that any outage at AES would take the full plant offline. In practice, the AES plant has two separate boilers, and while a full outage is possible, it is more likely that the plant would be partially de-rated rather than experience a full outage.

The HNEI-Telos Energy team is initiating a detailed modeling effort to quantify firm power requirements under various very high variable renewable scenarios, including continued development of solar and offshore wind.

**Emissions: biomass conversion significantly reduces emissions from fossil fuels**

The avoided oil consumption from the AES Biomass plant significantly reduces GHG emissions from oil, thus offering an opportunity for to emissions benefits. The net GHG reduction achievable by converting to biomass requires a full lifecycle analysis for the plant, fuel, and all transportation components. Biomass does have significant direct emissions when it is burned for electricity generation. However, the lifecycle of the biomass fuel also absorbs $CO_2$ in the atmosphere as the biomass is grown. Whether or not the lifecycle of the biomass is low carbon depends on the type of biomass, harvesting techniques, transportation, and whether the locations used for biomass harvesting are replanted.

While lifecycle analysis of biomass feedstock was not in the scope for this study, the HNEI team, as part of a separate request from the PUC, reviewed a large set of peer-reviewed studies for biomass combustion. This review indicates the potential for significant reductions in GHG compared fossil fuel use when full lifecycle emissions are considered.

**Cost: biomass as a hedge against future oil price volatility**

The cost benefits of any renewable project added to the Oʻahu grid will depend on the avoided generation from existing thermal resources and displaced steam oil generation. These costs include reduced fuel consumption, avoided variable operations and maintenance (VO&M), and startup and shutdown costs. Because these generation costs are primarily (i.e. >95%) attributed to reduced fuel costs, they are referred to throughout this section as avoided fuel savings.

As shown previously in Figure 1, operation of the AES biomass generation would displace energy from the existing steam oil fleet. While increased generation from AES would increase the utility's total PPA payment, these costs would be at least partially offset by savings from reduced oil consumption. At a $70/bbl price of oil, the total production costs with the AES Biomass conversion are higher by approximately $55 million per year, regardless of how much the plant runs. This is because the variable cost component of the AES Biomass (i.e. fuel cost and O&M expenses) is roughly equal to the steam oil variable cost at $70/bbl, with the remaining costs attributed to the fixed capital cost for the conversion.

At this oil price, the AES conversion would add approximately 0.75 cents/kWh to ratepayers. For an average residential customer who uses 500 kWh per month, this is equal to $3.70/month (or a 2.4% increase). A table of the AES payments, avoided costs, and net benefits are provided in Table 1 across a range of AES utilization.

However, global oil prices are volatile. Over the past 10 years, oil prices have ranged from a low of $29/bbl in 2016 (excluding negative pricing during the COVID-19 pandemic) and a high of $112/bbl in 2011. Over the past five years, prices have fluctuated between $50-85/bbl. Because Hawaiʻi imports oil for most of its electricity consumption, the state's residents and utility customers are exposed to this fuel price volatility. Biomass, on the other hand, can be contracted on a long-term basis with fixed fuel costs.

| | **Property** | **$70/bbl Oil Price** | | | | **$100/bbl Oil Price** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **AES Utilization** | AES Capacity Factor (%) | **0%** | **40%** | **60%** | **87%** | **0%** | **40%** | **60%** | **87%** |
| | AES Generation (GWh) | | 625 | 941 | 1,366 | | 625 | 941 | 1,366 |
| | RPS Contribution (%) | | 8% | 13% | 19% | | 8% | 13% | 19% |
| **AES Payments** | AES Energy Payment (k$)* | | 76,614 | 113,358 | 163,225 | | 76,614 | 113,358 | 163,225 |
| | AES Capacity Payment (k$) | | 54,000 | 54,000 | 54,000 | | 54,000 | 54,000 | 54,000 |
| | Total AES Payment (k$) | | 130,614 | 167,358 | 217,225 | | 130,614 | 167,358 | 217,225 |
| | Total AES Payment ($/MWh) | | 209 | 178 | 159 | | 209 | 178 | 159 |
| **System Costs** | HECO Production Costs (k$)** | **475,510** | **399,990** | **366,187** | **313,265** | **672,403** | **564,672** | **516,448** | **440,810** |
| | Avoided Costs (k$) | | 75,520 | 109,323 | 162,245 | | 107,731 | 155,955 | 34,699 |
| | Avoided Costs ($/MWh) | | 121 | 116 | 119 | | 172 | 166 | 25 |
| | Total Production Costs (incl. AES) (k$) | 475,510 | 530,604 | 533,544 | 530,490 | 672,403 | 695,286 | 683,805 | 658,036 |
| **Net Benefits** | **Net Benefits (Costs) (k$)** | | -55,094 | -58,035 | -54,980 | | -22,883 | -11,402 | 14,367 |
| | **Net Benefits (Costs) ($/MWh of AES)** | | -88 | -62 | -40 | | -37 | -12 | 11 |
| | **Net Benefits (Costs) (c/kWh of sales)** | | -0.7 | -0.8 | -0.7 | | -0.3 | -0.2 | 0.2 |

*Energy Payment = Fuel + VO&M costs, based on utilization

**Includes fuel costs and VO&M costs for HECO generation and Kalaeloa CC. Does not include AES costs or renewable PPAs, or other fixed costs

Table 1. Avoided Cost Calculations for AES Biomass Conversion at Increasing Utilization.

Figure 4 illustrates the net benefits (costs) of the AES Biomass conversion across a range of oil prices, from $50/bbl to $120/bbl. This indicates a break-even cost at $100/bbl of oil, and costs ranging from 0.5 cents/kWh to 1.2 cents/kWh with oil prices between $50-80/bbl.

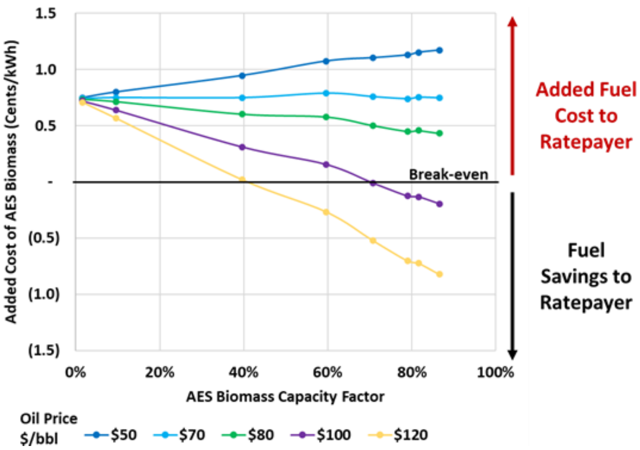


Figure 4. Cost of AES Biomass Conversion at Varying Oil Prices.

It should be noted that this cost-benefit analysis only includes the avoided energy benefits for the reduction in fuel use. It does not include other potential benefits attributed to the AES conversion, including capacity reliability benefits, emissions reductions, reduction in land use, etc.

It should also be noted that a portion of the biomass required for this plant could be locally sourced. The jobs growth and increased self-sufficiency of the islands has not been considered in this analysis.

**Conclusions**

The results of this feasibility study indicate that further consideration of biomass in O‘ahu’s energy future is warranted. The AES biomass conversion would significantly accelerate O‘ahu’s clean energy transition without inhibiting or delaying the continued growth of solar resources (both distributed and utility-scale). Since this project would largely use existing infrastructure, it is expected that the contract length for the biomass operations could be flexible. This has the potential to be a low-regret option to achieving a large increase in renewable energy without excluding new renewable resources that may be developed in the future.

Two issues, however, do require more in-depth study. The costs of the proposed AES biomass conversion are based on this preliminary analysis are high relative to other resource types. However, low cost solar cannot get us to 100%. Other fully dispatchable resources (new or existing) will be needed. Secondly, while it is clear that use of biomass will significantly reduce GHG emissions from our fossil fleet, the net benefits of this transition requires a full life-cycle assessment of the plant conversion and potential fuel sources.

*Funding Source*: Office of Naval Research; Energy Systems Development Special Fund

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