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ANTHONY KOYAMATSU
Director
Environmental Division

October 17, 2018

SENT VIA U.S. MAIL
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RETURN RECEIPT REQUESTED

Ms. Marianne Rossio, P.E.
Manager, Clean Air Branch
State of Hawaii Department of Health
2827 Waimano Home Road
Hale Ola Building, Room 130
Pearl City, Hawaii 96782

Subject: **Greenhouse Gas (GHG) Emissions Reduction Plan Update**
Hawaiian Electric Companies

Dear Ms. Rossio:

Enclosed are two (2) copies of the Hawaiian Electric Companies' updated GHG Emissions Reduction Plan dated October 15, 2018 along with certification by Hawaiian Electric's Vice President of Power Supply. This update incorporates the revised emissions baseline and cap for one of Hawaiian Electric's partners, Kalaeloa Partners, LP, and addresses comments received from the Department of Health Clean Air Branch on the version submitted on February 28, 2018.

If you have any questions or concerns regarding this submittal, please contact Greg Narum at 808-543-4401 or greg.narum@hawaiianelectric.com.

Sincerely,

[signature]

Enclosures: 1) GHG Emissions Reduction Plan dated October 15, 2018 (2 copies)
2) GHG ERP Responsible Official Certification

Electronic Distribution:
cc (w/Encl.): Michael A. Madsen, DOH Clean Air Branch (michael.madsen@doh.hawaii.gov)

Certification

This certification applies to the October 15, 2018 update of the **Greenhouse Gas Emissions Reduction Plan for the Hawaiian Electric Companies** *that is being submitted to the Department of Health in accordance with HAR 11-60.1 Subchapter 11.*

I certify that I have knowledge of the facts set forth therein, that the same are true, accurate, and complete to the best of my knowledge and belief, and that all information not identified by me as confidential in nature shall be treated by the Department of Health as public record.

Name: Robert C. Isler
Title: Vice President, Power Supply, Hawaiian Electric Company

Signature: ______________________ Date: 10/15/2018

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Greenhouse Gas Emissions Reduction Plan for the Hawaiian Electric Companies

Submitted to Hawai'i Department of Health in accordance with HAR 11-60.1 Subchapter 11

October 15, 2018 Update

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

Table of Contents

Record of Revisions

Revision No.	Date	Revisions
0	06/30/2015	Original submission to DOH
1	09/08/2017	Designate Campbell Industrial Park Generating Station (CIPGS) CSP No. 0548-01-C as the Main Permit for Partnership; update facility-specific GHG caps in Table A-1 based on latest forecasts; miscellaneous text updates.
2	02/28/2018	Add AES Hawaii, Kalaeloa Partners LP (KPLP), and Hamakua Energy Power (HEP) as partners; revise GHG Partnership section; add Monitoring explanation.
3	10/15/2018	Change KPLP baseline and cap in Table A-1 to Tier 3 basis per agreement with DOH. Updates to Table 1 and text to address DOH comments rec'd 9/21/2018.

Introduction

Hawaiian Electric Company, Inc. (Hawaiian Electric) supports Hawai'i's goal established in Act 234 of lowering GHG emissions in the state to 1990 levels.

In accordance with Hawai'i Administrative Rules (HAR) under §11-60.1 Subchapter 11, which were adopted to implement Act 234, facilities that have the potential to emit more than 100,000 tons per year of CO_2e (carbon dioxide equivalent) emissions are designated as "Affected Sources." Affected Sources are required to reduce their GHG emissions at least 16% from their 2010 baseline levels by January 1, 2020 unless the owner or operator can substantiate that a 16% reduction is unattainable and Hawai'i Department of Health (DOH) approves a lesser reduction.[1] The Act 234 regulations also allow Affected Sources to partner with one another to combine their facility-wide GHG emissions caps to leverage emission reductions among partnering facilities to meet the combined GHG emissions caps.[2]

Hawaiian Electric and its subsidiaries, Hawai'i Electric Light Company, Inc. (Hawai'i Electric Light) and Maui Electric Company, Ltd. (Maui Electric), (collectively, "Hawaiian Electric Companies" or "Companies") operated eleven generating facilities in 2010 that each had the potential to emit more than 100,000 tons per year of CO2e and, thus, qualify as Affected Sources. Act 234 regulations require an Affected Source to prepare a GHG Emissions Reduction Plan (ERP) that is used by DOH to set the Affected Source's CO_2e emissions cap. The ERP also demonstrates how that cap will be met by January 1, 2020.[3] The Hawaiian Electric Companies have prepared this ERP to satisfy that requirement.

The Hawaiian Electric Companies acquire power from Independent Power Producers (IPPs) and from renewable energy sources (e.g., rooftop solar panels, wind farms, utility scale solar installations) that are used to meet customer demand. In the event an IPP has unplanned outages or there is reduced output from renewable sources (e.g., due to cloudy or rainy weather, lack of wind, etc.), the Hawaiian Electric Companies must make up for the generation shortfall by increasing generation from other generating sources. Historically, the shortfall has been made up by the Companies' Affected Sources, thereby increasing their GHG emissions. In the future, the commissioning of new, rapid-response generators such as the Schofield Generating Station in 2018 as well as battery energy storage systems (BESS) charged by renewable energy sources will allow shifting some of that load to facilities that have much lower GHG emissions.

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[1] HAR 11-60.1-204(c)

[2] HAR 11-60.1-204(d)(6)(A)

[3] HAR 11-60.1-204

GHG Reduction Partnership

This section explains the partnership approach used by the Hawaiian Electric Companies and its Partners in preparing their GHG ERPs.

The power generation facilities operating on each of Hawai'i's islands are highly interdependent. If one or more of them cannot produce their scheduled power output, the other facilities on the island must generate more power than planned to make up for the shortfall. A scheduled or unscheduled outage that takes a major generating unit offline for an extended period can significantly shift GHG emissions from one facility to another. Assigning firm GHG emissions caps to individual facilities does not provide sufficient flexibility to accommodate those types of system upsets that are a natural part of system operation.

For these reasons, the Hawaiian Electric Companies and three major Independent Power Producers (IPPs) have elected to use the partnering provisions in Act 234 Regulations[4] to create a Partnership involving all eleven of the Hawaiian Electric Companies' Affected Sources, the Hamakua Energy Power (HEP) facility, the AES Hawai'i facility, and the Kalaeloa Partners LP (KPLP) facility (collectively "Partnership Facilities" or "Partnership"). The Partnership has an overall GHG emissions cap that it commits to attain. Individual partnering facilities have site-specific GHG emissions reduction goals that are used to apportion penalties that may be assessed in the event the overall GHG emissions cap is exceeded. The DOH will include the site-specific goals as GHG emissions caps, along with implementing conditions, in each site's Covered Source Permit (CSP). Owing to the operating flexibility that partnering in this manner affords, the Partnership Facilities can commit to an aggregate 16% reduction of GHG emissions from their respective baselines for their facilities. The site-specific and overall GHG emissions reduction targets for the Partnership Facilities are listed in Table A-1 of Attachment A. The Power Supply Improvement Plan (PSIP) for the Hawaiian Electric Companies that was approved by the Hawai'i Public Utilities Commission (PUC) on July 14, 2017[5] is the blueprint for how that reduction will be accomplished.

The Hawaiian Electric Companies, HEP, AES Hawai'i, and KPLP are submitting separate ERPs for their facilities. The ERPs share the same GHG emissions reduction goals provided in Table A-1, but the individual plans explain the GHG baselines, monitoring, and other plan requirements specific to each partner.

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[4] HAR 11-60.1-204(d)(6)(A).

[5] *Hawaiian Electric Companies' PSIP Update Report,* PUC Docket 2014-0183. December 23, 2016.

Emission Reduction Plan Required Elements

Hawai'i Administrative Rule (HAR) §11-60.1-204(d) states the GHG Emissions Reduction Plan required of Affected Sources shall at a minimum include the following elements:

(1) ***Facility-wide Baseline Annual Emission Rate (tpy CO_2e).*** *Calendar year 2010 annual emissions shall be used as the baseline emissions to calculate the required facility-wide GHG emissions cap, unless another baseline year or period is approved by the director. Baseline emissions shall be determined in accordance with section 11-60.1-115, separated between biogenic and non-biogenic emissions, and exclude all emissions of noncompliance with an applicable requirement or permit limit. The owner or operator shall include the data and calculations used to determine the baseline emissions. If calendar year 2010 is deemed unrepresentative of normal operations, then the owner or operator may propose an alternate baseline annual emission rate....*[6]

Attachment A, Table A-1 lists the baseline GHG emissions for the Partnership Facilities. The Hawaiian Electric Companies' facilities all use 2010 calendar year emissions as their baselines. GHG emissions were calculated using the procedures specified in EPA's Mandatory GHG Reporting Rule (40 CFR Part 98, Subpart C). The Kahe, Waiau, and Honolulu facilities used Tier 3 level calculations specified in §98.33 and the other facilities used Tier 2 level calculations. All baselines shown in Table A-1 for the Hawaiian Electric Companies' facilities are as reported via EPA's e-GGRT system for 2010 except for Campbell Industrial Park Generating Station (CIPGS) and Shipman. For calendar year 2010 CIPGS and Shipman GHG emissions were lower than the 25,000 metric ton reporting threshold under Part 98 so GHG emissions reporting was not required.

(2) ***2020 Facility-wide GHG Emissions Caps.*** *Determine the facility-wide GHG emissions cap in accordance with subsection (c), using calendar year 2010 or the proposed GHG baseline emission rate determined by paragraph (1) above. If the required emissions cap requiring a sixteen percent (16%) emission reduction from baseline year emissions is deemed unattainable, the owner or operator shall provide [a justification and proposal for an alternative cap]....*

In determining whether or not the required GHG emissions cap is attainable, the owner or operator of an affected source shall first conduct the GHG control assessment described in paragraphs (3) to (5). Available EPA

[6] HAR 60.1-204(d)(1)

guidelines for GHG Best Available Control Technology analysis and GHG control measures by source type shall be used as applicable for this assessment.[7]

Attachment A, Table A-1 lists the overall and facility-specific GHG emissions caps the Partnership Facilities commit to achieving by January 1, 2020 with all their Affected Sources grouped into one Partnership. The overall GHG emissions cap reflects a 16% reduction in GHG from their GHG emissions baselines .

Table A-1 shows that the overall GHG emissions reduction target for the Hawaiian Electric Companies is 24.4%, which exceeds the overall 16% GHG emissions reduction for the Partnering Facilities because IPPs will continue to be preferentially dispatched since they are the lowest-cost power producers. Most of the generation displaced by renewable energy will come from reduced operation of Hawaiian Electric's Affected Sources.

One of the important benefits of the Partnership for customers is that it allows the GHG emissions reduction goal of Act 234 to be met while maintaining the lowest energy cost to customers.

Monitoring and Reporting to Demonstrate GHG Emissions Reductions

The Hawaiian Electric Companies' facilities will use the same procedures used to establish their GHG baseline emissions, as described in paragraph (1), to calculate their annual GHG emissions and demonstrate the Partnership's compliance with the GHG emissions reduction requirement. GHG emissions for each facility will be reported annually on EPA's e-GGRT system and semi-annually to the DOH.

The Hawaiian Electric Companies' facilities use the GHG emissions calculation procedures specified in 40 CFR Part 98, Subpart C. They are not required to use Continuous Emissions Monitoring Systems (CEMS) for GHG emissions monitoring and do not have all the necessary instrumentation to be able to do so.

(3) ***Available Control Measures.*** *Identify all available control measures with potential application for each source type, and all on-the-book control measures the facility is committed or will be required to implement affecting GHG emissions. At a minimum, the following shall be considered as applicable:*

(A) Available technologies for direct GHG capture and control;

(B) Fuel switching or co-fired fuels;

(C) Energy efficiency upgrades;

[7] HAR 60.1-204(d)(2)

(D) *Combustion or operational improvements;*

(E) *Restrictive operations;*

(F) *Planned upgrades, overhaul, or retirement of equipment;*

(G) *Outstanding regulatory mandates, emission standards, and binding agreements; and*

(H) *Other GHG reduction initiatives that may affect the facility's GHG emissions. Unless the owner or operator of the source has direct ownership or legal control over a GHG reduction initiative, that initiative cannot be relied upon as a proposed control strategy. Identification of GHG reduction initiatives, whether or not the owner or operator has ownership or legal control, will serve to highlight their potential importance for reducing GHG emissions in the state. The owner or operator of an affected source will only benefit from a GHG initiative if the initiative reduces or helps to reduce and maintain the source's GHG emissions below its permitted facility-wide GHG emissions cap.*[8]

Table 1 lists the potential GHG emissions control options cited above and their feasibility for the Hawaiian Electric Companies. ERP Attachments referenced in Table 1 further describe the GHG emissions control options and discuss their feasibility and costs.

[8] HAR 11-60.1-204(d)(3)

TABLE 1 - EVALUATION OF GHG EMISSIONS CONTROL OPTIONS

	GHG Control Option	Feasibility and Benefit
(A)	Carbon Capture and Storage (CCS)	Not Economically Viable - See Attachment B for details.
(B)	Fuel switching or co-firing fuels (Natural Gas)	Not Feasible – The Hawaiian Electric Companies explored importing liquefied natural gas. However, the PUC rejected that option as part of its decision to deny the merger of the Hawaiian Electric Companies with NextEra. See Attachment C for details about the potential GHG emissions benefits.
(C)	Fuel switching or co-firing fuels (Biofuels)	Not Feasible to do on a large scale – The Hawaiian Electric Companies are currently permitted and are burning limited quantities of biodiesel. Attachment D contains a discussion of the availability and cost of biodiesel.
(D)	Energy efficiency upgrades and combustion improvements	Attachment E summarizes the Hawaiian Electric Companies' evaluation of energy efficiency improvements available to their power generating units. No economically viable improvements were identified that would contribute significantly towards reducing GHG emissions.
(E)	Restrictive operations	If one of the generating facilities in the Hawaiian Electric Companies' electrical grids restricts operation to limit its GHG emissions, other facilities must operate more to meet customer demand so the result is that emissions are redistributed rather than reduced or eliminated. The Partnership concept provides flexibility for lower GHG emitting facilities to operate more to lower overall GHG emissions and Hawaiian Electric intends to do this as much as possible within system and economic constraints. However, the GHG emissions reductions available through this route are limited because the more efficient units (e.g., combined cycle combustion turbines) already operate preferentially because they tend to be lower cost generators.

(F)	Planned upgrades, overhaul, or retirement of equipment	As new renewable energy projects come online, the operation of existing fossil-fueled units can be reduced or ceased. The Hawaiian Electric Companies have deactivated or retired the following fossil-fuel units since the 2010 baseline year: • Shipman S3 and S4. Permanently decommissioned and CSP closed December 31, 2015. • Honolulu H8 and H9. Deactivated January 2014.
(G)	Outstanding regulatory mandates, emission standards, and binding agreements	Hawai'i set a 100 percent Renewable Portfolio Standard (RPS) for electrical generation by 2045. The Hawaiian Electric Companies' December 2016 Power Supply Improvement Plan (PSIP) describes how the Companies intend to accomplish that goal. EPA proposed the Affordable Clean Energy (ACE) Rule on August 31, 2018. It is not clear yet whether it will apply to the Hawaiian Electric Companies' oil-fired generating units. The emphasis of ACE Rule is to improve the efficiency of existing generators through measures to be adopted by the states.
(H)	Other GHG emissions reduction initiatives: Renewable Energy (RE) Projects: Wind, Solar, and Battery Energy Storage Systems (BESS) Deployment of new flexible, rapid response generation to enable more integration of renewable energy sources.	The Hawaiian Electric Companies' main strategy for lowering GHG emissions is to continue replacing fossil-fueled generation with utility-scale and distributed (e.g., rooftop solar) renewable energy sources. The December 2016 PSIP includes additional utility scale RE coming online between 2017 and 2019: Hawaiian Electric - 206.2 MW of new utility scale RE + 70MW BESS Maui Electric - 8.74 MW of new RE + 9MW BESS Hawai'i Electric Light - 3 MW of new RE. The December 2016 PSIP also describes new firm generation projects that provide the rapid response capability needed to work with the varying output from renewables. One of these is the Schofield Generating Station that came online in 2018.

(4) ***Technically Feasible Measures.*** *For any new control measure identified for the facility, eliminate all technically infeasible options based on physical, chemical, or engineering principles that would preclude the successful operation of the control with the applicable emission unit or source. Document the basis of elimination, and generate the list of technically feasible control options for further evaluation. All committed and required on-the-book measures shall remain on the list.*[9]

As noted above, Table 1 lists the potential GHG emissions control options and their feasibility. Attachments referenced in Table 1 further describe the GHG emissions control options and discuss their feasibility and costs.

(5) ***Control Effectiveness and Cost Evaluation.*** *List the technically feasible control options and identify the following for each control measure as applicable. All cost data shall be provided in present dollars.*

(A) Control effectiveness (percent pollutant removed);

(B) Expected emission rate (tons per year CO_2e, pounds CO_2e/kilowatt-hour);

(C) Expected emission reduction (tons per year CO_2e);

(D) Energy impacts (BTU, kilowatt-hour);

(E) Environmental impacts (other media and the emissions of other regulated air pollutants);

(F) Any secondary emissions or impacts resulting from the production or acquisition of the control measure; and

(G) Economic impact (cost effectiveness: annualized control cost, dollar/megawatt-hr, dollar/ton CO_2e removed, and incremental cost effectiveness between the control and status quo).

For committed or required on-the-books control measures and any other GHG control initiatives, identify at a minimum, items (A) through (C) above. Considering the energy, environmental, and economic impact, determine the GHG control or suite of controls found to be feasible in achieving the maximum degree of GHG reductions for the facility. Determine whether the required GHG emissions cap, pursuant to subsection (c) will be met. If an alternate cap must be proposed for approval, declare the proposed percentage GHG reduction and the alternate GHG reduction cap. Provide the justification and associated support information (e.g., references,

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[9] HAR 11-60.1-204(d)(4)

As noted above, Table 1 lists the potential GHG emissions control options and their feasibility. Attachments referenced in Table 1 further describe the GHG emissions control options and discuss their feasibility and costs.

(6) ***Proposed Control Strategy.*** *Present the listing of control measures to be used for implementation in meeting the required or proposed alternate 2020 facility-wide GHG emissions cap. Include discussion of the control effectiveness, control implementation schedule, and the overall expected GHG CO_2e emission reductions (tpy) for the entire facility. Owners or operators shall also consider the following:*

(A) *Affected sources may propose to combine their facility-wide GHG emissions caps to leverage emission reductions among partnering facilities in meeting the combined GHG emissions caps. If approved by the director, each partnering facility will be responsible for complying with its own adjusted GHG facility-wide emissions cap.*

(B) *Except for fee assessments and determining applicability to this section, biogenic CO_2 emissions will not be included when determining compliance with the facility-wide emissions cap until further guidance can be provided by EPA, or the director, through rulemaking.*

(C) *The approved facility-wide GHG emissions cap and the associated monitoring, recordkeeping, and reporting provisions will be made a part of the covered source permit, enforceable by the director.*[11]

The Hawaiian Electric Companies will collectively reduce their GHG emissions 16% from the 2010 baseline year, generally in accordance with the power generation forecasts described in their PSIP that was submitted in December 2016 and accepted by the PUC on July 14, 2017.[12] Although the PSIPs are not enforceable under Chapter 342B, HRS, Air Pollution Control, they do carry the weight of oversight by the PUC and public expectations.

The Hawaiian Electric Companies' GHG emissions reductions will result directly from increased state-wide reliance on renewable energy sources as detailed in the PSIP. The Hawaiian Electric Companies have consistently met, and exceeded, the RPS. For instance, in 2015 23.2% of the Companies' overall power generation was from renewable sources,[13] well ahead of the HCEI RPS goal of 15% by 2015.[14] In 2017,

[11] HAR 11-60.1-204(d)(6)

[12] Public Utilities Commission of the State of Hawai'i Decision and Order No. 34696. July 14, 2017.

[13] *2017-2018 Corporate Sustainability Report.* Hawaiian Electric Companies. Page 4.

[14] HRS §269-92(2). It should be noted that the RPS allows affiliated electrical utilities to aggregate their renewable portfolios. HRS §269-93. Accordingly, all GHG emissions reductions referenced in this section represent the aggregate renewable portfolios for Hawaiian Electric, Hawai'i Electric Light, and Maui Electric.

26.8% of the Companies' power generation was from renewable sources. The RPS goals have increased due to House Bill 623, signed into law by Governor David Ige on June 5, 2015, which establishes a new RPS goal of 100% renewables by 2045. In 2017, the GHG emissions from the combined Hawaiian Electric Companies were 20.0% lower than the 2010 baseline year. Continued progress towards the RPS and PSIP goals will assist GHG emissions from power generation to decline further.

The shutdown of Puna Geothermal Venture (PGV) due to the eruption of the Kilauea Volcano in 2018 caused a significant loss of renewable power for Hawai'i Electric Light, requiring fossil-fueled units on Hawai'i Island to operate at higher levels than had been anticipated. PGV had generated 25% to 30% of the total electricity used on Hawai'i Island. The need for fossil-fueled generation will likely continue for some time until PGV can be re-started or additional renewable generation can be established on the island. In spite of the nearly 200,000 tons per year increase in GHG emissions resulting from the PGV outage, the Hawaiian Electric Companies have elected not to petition for an equivalent increase in baseline emissions and GHG caps although that is an option under HAR 11-60.1-204(h).

As explained in Table 1 and the supporting attachments, the Hawaiian Electric Companies' evaluation of potential GHG emissions control measures identified no additional measures that are technically feasible and cost effective. Accordingly, the Companies do not propose to implement any GHG emissions controls.

As described earlier, the Hawaiian Electric Companies' eleven affected facilities are partnering with three IPPs to meet the GHG emissions reduction target. Table A-1 lists the overall GHG annual emissions limit for the Partnership Facilities along with site-specific GHG emissions limits for each of the Partnering Facilities.

The Hawaiian Electric Companies have designated Campbell Industrial Park Generating Station (CIPGS) as the Main Permit for their affected facilities. CIPGS's CSP will list the Total Partnership GHG emissions cap and the site-specific emissions caps for the Hawaiian Electric Companies' other facilities. The CSPs for the Hawaiian Electric Companies' other facilities will reference the CIPGS CSP for GHG emissions limits.

Table A-1: ERP Partnership Baseline $CO_{2}e$ Emissions and Proposed CSP Limits (1)

		Baseline		CSP Limits		
		CO2e Emissions		CO2e Reduction		CO2e Limit
Company	Covered Source	(metric tpy)	(tpy)	(%)	(tpy)	(tpy)
Hawaiian Electric (HE)	Kahe	2,518,411	2,776,073	23.1%	642,321	2,133,752
	Waiau	974,642	1,074,359	24.8%	266,074	808,286
	Honolulu	121,208	133,609	100.0%	133,609	0
	CIPGS	13,559	14,946	-259.6%	-38,794	53,740
HESubtotal		3,627,821	3,998,988	25.1%	1,003,210	2,995,778
Maui Electric (ME)	Kahului	209,414	230,839	33.0%	76,206	154,633
	Maalaea	562,012	619,512	25.8%	159,649	459,864
	Palaau	25,615	28,236	6.3%	1,782	26,454
ME Subtotal		797,041	878,587	27.0%	237,636	640,951
Hawai'i Electric Light (HEL)	Kanoelehua-Hill	202,106	222,784	22.6%	50,328	172,456
	Keahole	173,623	191,387	-26.6%	-50,821	242,208
	Puna	90,438	99,691	68.2%	67,944	31,747
	Shipman	9,246	10,192	100.0%	10,192	0
HEL Subtotal		475,413	524,053	14.8%	77,642	446,411
Hawaiian Electric Companies		**4,900,275**	**5,401,629**	**24.4%**	**1,318,488**	**4,083,141**
AES Hawai'i		**1,525,526**	**1,681,605**	**-0.6%**	**-10,000**	**1,691,605**
Hamakua Energy Power		**165,992**	**182,975**	**16.0%**	**29,276**	**153,699**
Kalaeloa Partners, LP		**993,198**	**1,094,813**	**0.0%**	**0**	**1,094,813**
Partnership Total		**7,584,991**	**8,361,022**	**16.00%**	**1,337,764**	**7,023,258**

Notes:

(1) Excludes biogenic CO2 emissions.

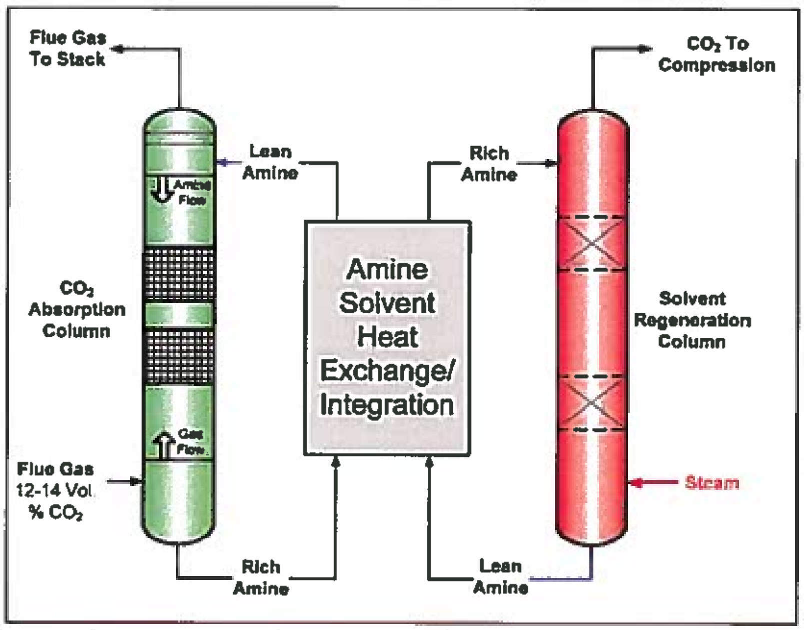
(2) Selections of facility emissions baselines are described in the individual GHG Emission Reduction Plans for the Hawaiian Electric Companies, AES Hawai'i, Kalaeloa Partners, LP (KPLP), and Hamakua Energy Power (HEP).

(3) CIPGS (Campbell Industrial Park Generating Station) is designated as the Main CSP for the Hawaiian Electric Companies' Emissions Reduction Plan.

Carbon Capture and Storage

Carbon Capture and Storage (CCS) is composed of two major functions; CO_2 capture and CO_2 storage. A number of methods may potentially be used for separating the CO_2 from the exhaust gas stream, including adsorption, physical absorption, chemical absorption, cryogenic separation, and membrane separation (Wang et al., 2011). Many of these methods are either still in development or not suitable for treating power plant flue gas due to the characteristics of the exhaust stream (Wang, 2011; IPCC, 2005). Of the potentially applicable post-combustion CO_2 capture options, the use of an amine solvent such as monoethanolamine (MEA) it is the most mature and well-documented technology (Kvamsdal et al., 2011). Figure B-1 illustrates the amine-based post-combustion capture process.

FIGURE B-1 SCHEMATIC DIAGRAM OF AMINE-BASED CO_2 CAPTURE PROCESS



Source: Interagency Task Force on Carbon Capture and Storage, 2010

EPA generally considers post-combustion CO_2 capture with an amine solvent to be technically feasible for natural gas fired combined cycle combustion turbines and coal fired power plants. However, this technology has not been demonstrated on simple cycle combustion turbines and reciprocating engines. Part of the reason is that the flue gas temperature from simple cycle turbines and reciprocating engines is much higher than from combined cycle turbines and boilers so the gases have to be cooled prior to scrubbing going to the CO_2 absorption column. While still feasible, that adds cost and makes it less economically practical. A more fundamental difficulty with using amine absorption for combustion turbines of either type as well as reciprocating engines is that the CO_2 concentration in the flue gas is lower than 6 percent. That concentration is much lower than other types of power plants, such as coal fired power plants, where the CO_2 concentration may be as high as 12-15 percent by volume in the post combustion flue gas stream. As a result, the amine system equipment has to be more than twice as large for the same amount of CO_2 captured. That greatly increases the treatment cost. Although significant challenges exist, CCS cost estimates are provided in Tables B-1 and B-2. The data in the tables do not reflect the higher cost associated with treating low-CO_2 concentration flue gases from combustion turbines and reciprocating engines.

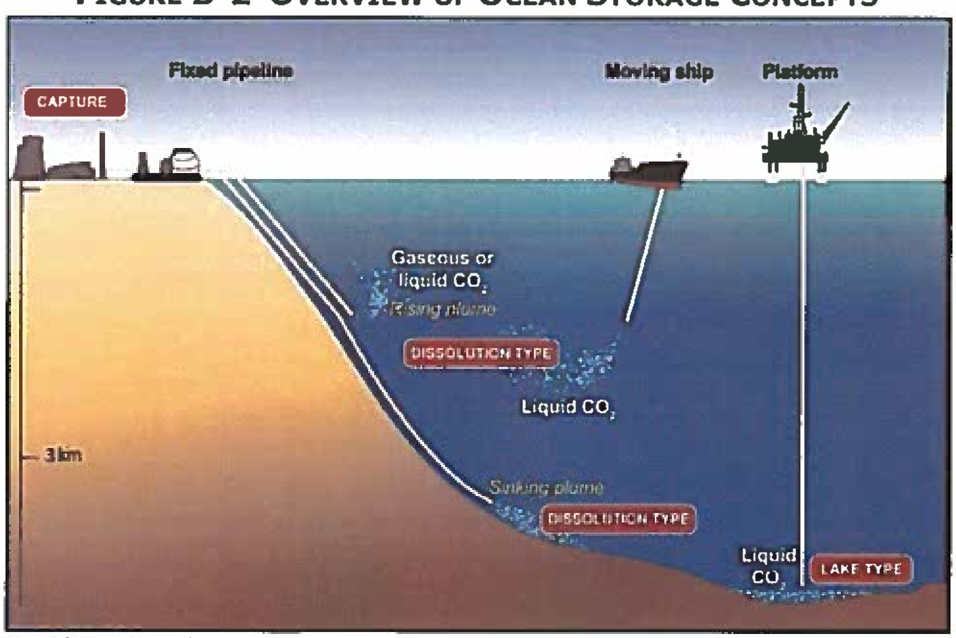
Hawai'i's remote location imposes many additional challenges implementing CO_2 storage that are not present for continental U.S. sources. Hawaiian Electric is not aware of any proven CO_2 geological storage sites on Hawai'i. Therefore, ocean storage, i.e., direct CO_2 release into the ocean water column or onto the deep seafloor, appears to be the most readily available CO_2 storage option.

As shown in Figure B-2, CO_2 ocean storage potentially could be implemented in two ways:

- By injecting and dissolving CO_2 into the water column (typically below 1,000 meters) via a fixed pipeline or a moving ship, or
- By depositing CO_2 via a fixed pipeline or an offshore platform onto the sea floor at depths below 3,000 m, where CO_2 is denser than water and is expected to form a "lake" that would delay dissolution of CO_2 into the surrounding environment.

Ocean storage and its ecological impacts are still in the research phase and the legal status of intentional ocean storage is unknown (Herzog, 2010; IPCC, 2005; Purdy, 2006).

FIGURE B-2 OVERVIEW OF OCEAN STORAGE CONCEPTS



Source: IPCC, 2005

Attachment B – Carbon Capture and Storage

The first step to costing CCS is calculating CO_2 emission rates. CO_2 emissions from power generation are a function of fuel type and the heat rate of the generating unit. Due to the large number of generating units and the various current and future fuel types, the costing is based on typical generating unit configurations.

Table B-1 lists the estimated total annual cost on a $/million Btu (MBtu) basis to add CCS based on fuel type. The estimate includes the amine absorber system cost, the onshore CO_2 storage cost, and the ocean injection cost. The total annual estimated cost ranges from $5.64 to $7.99 per MBtu of heat input.

As noted earlier, due to the absence of suitable subterranean formations, geological storage does not appear to be a viable option in Hawai'i. Even if available, using geological storage instead of ocean storage would not lower the cost. The listed estimated total ocean CO_2 storage cost of $13.80 per ton ($2.00 + $4.81 + $6.99 = $13.80) is actually lower than the estimated total cost for geological storage ($8.53 to $19.51 per ton)[15].

Table B-2 lists the estimated total annual cost for CCS on a $/kW basis for various fuel and generating unit types. These costs range from 7¢ to 10¢ per kWh based on maximum operation. These costs would be higher based on actual operating levels. That means that power cost to customers would have to increase 25% or more from 2016 rates, depending on location, to pay for CCS.

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[15] Table 9 of the National Energy Technology Laboratory report "Quality Guidelines for Energy System Studies: Estimating Carbon Dioxide Transport and Storage Costs" (DOE/NETL-2013/1614), dated March 14, 2013.

Attachment B – Carbon Capture and Storage

TABLE B-1 ESTIMATED TOTAL ANNUAL CCS COST ($/MBTU)

Carbon Capture and Storage (CCS) Component	Cost ($/ton CO_2 Captured)	CO_2 Emissions[1] (lb/MMBtu)	% Captured[2]	CO_2 Emissions Captured (lb/MMBtu)	Total Annual Cost ($/MMBtu)
		No. 6 Fuel Oil			
CO_2 Capture and Compression[3]	93.44	165.6	90%	149	$6.96
Onshore CO_2 Storage[4]	2.00				$0.15
Ship transport to injection ship[4]	4.81				$0.36
Injection ship, pipe and nozzle[4]	6.99				$0.52
Total Cost (Biodiesel)	107.24				$7.99
		No. 2 Fuel Oil			
CO_2 Capture and Compression[3]	93.44	163.1	90%	147	$6.87
Onshore CO_2 Storage[4]	2.00				$0.15
Ship transport to injection ship[4]	4.81				$0.35
Injection ship, pipe and nozzle[4]	6.99				$0.51
Total Cost (Diesel)	107.24				$7.88
		Natural Gas			
CO_2 Capture and Compression[3]	93.44	117.0	90%	105	$4.91
Onshore CO_2 Storage[4]	2.00				$0.11
Ship transport to injection ship[4]	4.81				$0.25
Injection ship, pipe and nozzle[4]	6.99				$0.37
Total Cost (Natural Gas)	107.24				$5.64

Notes:

1. Emission factors from the Mandatory Greenhouse Gas Reporting rule (40 CFR Part 98 Subpart C, Table C-1).
2. Typical value for amine absorber systems (Interagency Task Force on Carbon Capture and Storage, 2010; NETL, 2013).
3. The CO_2 capture and compression cost is based on information presented in Figure III-1 of the Report of the Interagency Task Force on CCS, dated August 2010. The listed dollar per ton of CO_2 captured is the cost of applying post-combustion CCS to an existing natural gas fired combined cycle power plant. The listed cost ($103 per metric ton or $93.44 per ton) is based on continuous operation (8,760 hrs per unit per year at base load for each fuel type).
4. Costs are from Table 6.6 of the IPCC Special Report on Carbon Dioxide Capture and Storage, dated 2005.

Table B-2 Estimated Total Annual CCS Cost ($/KWh)

Unit Type	Typical Heat Rate (Btu/kWh)	Fuel Type	Total Annual Cost ($/MMBtu)	CO_2 Removal Cost ($/kWh)
Boiler	12,000	No. 6 Fuel Oil	$7.99	0.10
		No. 2 Fuel Oil	$7.88	0.09
		Natural Gas	$5.64	0.07
Simple Cycle Combustion Turbine	9,500	No. 2 Fuel Oil	$7.88	0.09
		Natural Gas	$5.64	0.07
Combined Cycle Combustion Turbine	7,500	No. 2 Fuel Oil	$7.88	0.09
		Natural Gas	$5.64	0.07
Reciprocating Engine	8,000	No. 2 Fuel Oil	$7.88	0.09
		Natural Gas	$5.64	0.07

Note - Costs are based on continuous operation at base load. Costs based on actual operating levels would be higher.

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Natural Gas Conversion GHG Emissions Reduction

The Hawaiian Electric Companies pursued importation of liquefied natural gas (LNG) to lower fuel costs and air emissions, including GHG. However, after the PUC denied the merger of the Hawaiian Electric Companies with NextEra[16] the Companies withdrew their application for approval of LNG Supply Agreements.

Substitution of natural gas fuel can significantly reduce GHG emissions from power generation. To the extent that LNG replaces no. 2 (diesel) fuel oil and no. 6 fuel oil, GHG emissions are 28 to 30 percent lower per million Btu (MBtu) of fuel heat input as shown by the emissions factors in Table C-1. Net GHG emissions are reduced by a lesser amount, probably in the 25-28% range, because more heat input is typically required from gas than oil for the same amount of power generated. It is unlikely that LNG would make up 100% of the Companies' fuel consumption so the overall GHG reduction would be correspondingly lower.

TABLE C-1 NATURAL GAS CONVERSION CO_2 EMISSIONS REDUCTION CALCULATION

Fuel	GHG Pollutant[1]	Emission Factor[2] (kg/MMBtu)	Global Warming Potential[3]	Total GHG Emissions as CO_2e (lb/MMBtu)
No. 6 Fuel Oil	CO_2	75.10	1	165.6
	N_2O	6.0E-04	298	0.3942
	CH_4	3.0E-03	25	0.1653
			Total CO_2e =	**166.2**
No. 2 Fuel Oil	CO_2	73.96	1	163.1
	N_2O	6.0E-04	298	0.3942
	CH_4	3.0E-03	25	0.1653
			Total CO_2e =	**163.7**
Natural Gas	CO_2	53.06	1	117.0
	N_2O	1.0E-04	298	0.0657
	CH_4	1.0E-03	25	0.0551
			Total CO_2e =	**117.1**
No. 6 Fuel Oil to Natural Gas Reduction = 29.5%				
No. 2 Fuel Oil to Natural Gas Reduction = 28.4%				

Notes:

1. Greenhouse Gas (GHG) pollutants from the Mandatory Greenhouse Gas Reporting rule (40 CFR §98.32).
2. Emission factors from the Mandatory Greenhouse Gas Reporting rule (40 CFR Part 98 Subpart C, Tables C-1 and C-2).
3. Global Warming Potentials from the Mandatory Greenhouse Gas Reporting rule (40 CFR Part 98 Subpart A, Table A-1).

[16] Public Utilities Commission of the State of Hawai'i Decision and Order No. 33795. July 15, 2016.

Attachment D – Biofuel Conversion GHG Emissions Reduction

Biofuel Conversion GHG Emissions Reduction

1. Availability

Biodiesel has been used as fuel for power generation on a limited scale but there is not enough supply to replace a significant portion of the fuel consumed by the Hawaiian Electric Companies. According to the U.S. Energy Information Administration (EIA) Biodiesel Production Report for July 2018, biodiesel (as B100) production capacity in Hawai'i was only about 6 million gallons per year (MGY). Columbia Industrial Park (CIPGS) alone burned 7.7 million gallons in 2017. U.S. production capacity was 2370 MGY but only 209 MGY of that was on the west coast where delivery to Hawai'i would be practical. By comparison, the Hawaiian Electric Companies used 370 million gallons of residual and distillate fuels in 2013.

In order for biodiesel to become sufficiently available to provide fuel for the State's electricity needs, dedicated energy crops would be required. But it is uncertain whether those crops would be adequate for the competing fuel needs throughout the State. Furthermore, biodiesel production is constrained by limited land availability and unpredictable financial incentives. A 2010 study on the potential for biofuel production in Hawai'i concluded that biodiesel produced from waste fats, oils, and greases would account for only one half of one percent of current diesel fuel usage (B&V, 2010). The same study estimated the theoretical biodiesel potential from waste oil as 2 to 2.5 million gallons per year (MGY).

Hawaiian Electric recently obtained a contract with Pacific Biodiesel to purchase approximately 3 MGY of biodiesel, primarily for CIPGS. At this time, Pacific Biodiesel is the only producer of biodiesel located in the State of Hawai'i. Another company, Imperium Renewables Hawai'i, announced plans to develop and build a biodiesel plant in Kapolei (O'ahu) several years ago but the project was unsuccessful due to financial reasons. Subsequently, the PUC rejected Hawaiian Electric's proposal to import biodiesel from Imperium's production plant in Washington State because of high costs. To the extent possible, Hawaiian Electric and the PUC would prefer to use locally-produced biofuels. But there simply is not enough biodiesel supply available to significantly lower Hawaiian Electric's greenhouse gas emissions without drastically increasing the cost.

2. Cost

Table D-1 summarizes Hawaiian Electric's April 2015 fuel price forecasts. Historically, biodiesel has not been economically competitive compared to petroleum diesel without some type of governmental incentive. Our forecast shows that through 2019, the price of biodiesel will be approximately double that of our current fuel mix.

In addition to fuel cost, capital cost would be necessary to provide the infrastructure for receiving and storing biodiesel. Indirect costs such as permitting, performance testing, and engineering would likely add to the overall cost of switching to biodiesel. From an energy standpoint, biodiesel is similar to traditional diesel but contains about 7-10% less energy per gallon. Thus, the cost of biodiesel compared to diesel is higher but the energy content is lower.

Attachment D – Biofuel Conversion GHG Emissions Reduction

Biodiesel prices are expected to continue to rise. Although current generation biodiesel production facilities are more efficient and benefit from economies of scale, feedstock costs have remained high (B&V, 2010). Generally, waste oils are the least expensive but are not always available in large quantities. Furthermore, the U.S. biodiesel industry is highly dependent on financial incentives such as the Federal blender tax credit. The unpredictability of the biofuel market does not align with Hawaiian Electric's priority to provide reliable and low cost electricity. Further, we believe that it is questionable whether the PUC will approve large-scale conversions to biodiesel because of the potential cost impact on the Companies' customers.

TABLE D-1 BIODIESEL FUEL COST COMPARISON

Hawaiian Electric's 2018 Fuel Price Forecast				
	$/million Btu			
Year	No. 2 Diesel	LSFO	ULSD	Biodiesel
2018	15.82	13.08	16.88	31.84
2019	14.96	12.17	16.02	31.76
2020	15.86	12.99	16.96	32.93
2021	16.20	13.26	17.32	33.71

References

EIA (U.S. Energy Information Administration), 2015. "Monthly Biodiesel Production Report," dated March 2015.

B&V (Black and Veatch Corp.), 2010. "The Potential for Biofuels Production in Hawai'i," dated January 2010.

Hawaiian Electric, 2018 Fuel Price Forecast. Received from C. Reyes 7/6/2018.

Potential Energy Efficiency Improvements

Improving the efficiency when fuel energy is converted to usable power output reduces the amount of fuel that has to be combusted to satisfy power demand, in turn decreasing the emissions of greenhouse gases and other air pollutants that are created in the combustion process. Additionally, improved energy efficiency reduces the cost of power generation because of the lower fuel requirement.

Energy efficiency of power generating units can be improved though changes to technology (equipment), processes, and practices. But most of the cost-effective improvements available to power generators have already been made to reduce fuel cost since fuel is such a large part of the total cost of power generation. That is especially true for Electrical Generating Units (EGU) like Hawaiian Electric's that burn oil, which is a relatively high cost fuel. Energy efficiency improvement is one of the four Building Blocks that EPA relied on to develop its proposed *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units.*[17] In the preamble to the proposed rule EPA stated that they decided not to include efficiency improvement by oil-fired EGUs as an element of their Best System for Emissions Reduction (BSER) evaluation for GHG emissions because the potential GHG reductions are small compared to the reductions available from other types of power generation.[18]

Nevertheless, potential energy efficiency improvements for the Hawaiian Electric Companies' boilers, combustion turbines, and diesel electric generator sets are discussed in this section.

Boilers

The major portion of the Hawaiian Electric Companies' power generation comes from boilers that power steam turbine electric generators. The Hawaiian Electric Companies operate their boilers as efficiently as practicable. An important incentive for doing so is that the PUC establishes efficiency standards that must be met for the Company to fully recover the cost of the fuel used in power generation. Hawaiian Electric assures that its boilers operate at optimal energy efficiency a number of ways. One is by daily tracking and reporting of Heat Rate (HR) for each unit. Heat Rate, a measure of overall power generation efficiency that is commonly used in the power generation industry, is the ratio of the total fuel energy input divided by the net amount of power exported to customers, usually reported as Btu of fuel energy consumed per Kilowatt-hour of power exported (Btu/KWh). The lower the Heat Rate, the more efficiently the unit is operating. Heat Rate trends are a sensitive indicator of efficiency changes somewhere in the system. The Hawaiian Electric Companies also have aggressive Heat Rate improvement programs that follow the guidelines developed by the Electric Power Research

[17] 79 Fed. Reg. 34830, June 18, 2014.

[18] Ibid. p. 34877.

Institute (EPRI).[19] Those guidelines are based on the best practices used in the industry for improving and maintaining energy efficiency.

Maui Electric's four boilers and Hawai'i Electric Light's two boilers underwent energy assessments and tune-ups in 2014 that were required by 40 CFR Part 63 Subpart JJJJJJ, NESHAP for Industrial, Commercial, and Institutional Boilers Area Sources. The assessments, performed by a certified independent combustion engineer, concluded that the overall condition of the boilers is good and that good efficiency practices are followed. All the Maui Electric and Hawai'i Electric Light boilers are tested annually to confirm their efficiency and tune-ups are required under Subpart JJJJJJ once every five years.

Hawaiian Electric's boilers compare favorably for energy efficiency with other oil-fired EGUs in the U.S. The Energy Information Administration (EIA) collects and publishes Heat Rate data for several categories of EGUs. For the 2009 to 2013 period, EIA reported that the average HR for petroleum-fired EGUs was 10.9 MBtu/MWh.[20] By comparison, Hawaiian Electric's fourteen boilers on O'ahu averaged lower than 10.6 MBtu/MWh Heat Rate in the first 6 months of 2015. That is very good performance given the Hawaiian Electric boilers' operating rates.

Traditional style power plants were designed to operate near full capacity, often termed base-loaded, where they are most efficient. Operating them at lower and varying loads reduces their efficiency. Hawaiian Electric's boilers operate below full capacity. During 2012 through 2014, for instance, their average operating load was less than 60% of online capacity. There are two reasons for the lower load. One is that, unlike utilities on the mainland, Hawaiian Electric operates an isolated system. It cannot draw power from neighboring utilities in the event of system upsets so it must be entirely self-sufficient. To protect against power outages, Hawaiian Electric keeps enough unused generation capacity online as spinning reserve to absorb unexpected loss of the largest generation facility that is operating at any time.

Another factor that keeps operating load lower than ideal is imposed by the increasing amount of renewable energy that has been integrated into Hawaiian Electric's system. The output for renewable energy sources such as solar and wind is variable and intermittent because clouds reduce solar panel output and variable wind speeds reduce windmill output. Consequently, Hawaiian Electric's boilers have to vary their operation in order to match overall system output with demand. The result of those constraints on operating load is that Hawaiian Electric's boilers typically have to operate well below their peak efficiencies. Despite these constraints, as noted above, their HRs are competitive with those of mainland utilities, which generally do not have the same constraints.

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[19] *Heat Rate Improvement Guidelines.* EPRI, Palo Alto, CA: 2012. Publication 1023913.

[20] *Electric Power Annual.* U.S. EIA. March 23, 2015 release, Table 8.1.

Attachment E – Potential Energy Efficiency Improvements

Combustion Turbines

Combustion Turbines (CT) represent the Hawaiian Electric Companies' second-largest source of power generation. The Company operates three CTs on O'ahu, four on Maui, and five on Hawai'i Island.

The energy efficiency of CTs is highest when they operate in combined cycle mode rather than simple cycle. In simple cycle, the hot gases from the turbine are exhausted to the atmosphere, whereas in combined cycle hot exhaust gases pass through a heat recovery steam generator, where steam passes through a turbine to generate additional power.

All four of Maui's and two of Hawai'i Island's CTs are capable of operating in combined cycle mode. No other significant energy efficiency improvements have been identified.

The remaining three CTs on Hawai'i Island and three on O'ahu are simple cycle units. Although their energy efficiency could be improved by converting them to combined cycle, the Companies evaluated doing so and concluded that it would not be feasible given the function that the simple cycle CTs serve on the current system. These units operate less than 10 percent of the time and instead are used to provide fast response power in case of shortages on the system. Unlike boilers, which take a long time to start up, simple-cycle CTs can be started up fairly quickly when needed. In contrast, it takes significantly longer to bring a combined-cycle CT fully online. Operating the current simple-cycle CTs in combined-cycle mode would defeat much of the reason they are used. Hawaiian Electric has not identified any energy efficiency improvements for its CTs that fit within the current design of its system. That does not rule out system design changes that could accommodate combined cycle combustion turbines; however, such changes could not be implemented before 2020, the compliance date for Act 234 units.

Diesel Electric Generators

Diesel electric generators (DEGs) have generally lower power output capability than boilers or combustion turbines and are mainly used to serve lower loads, typically in remote locations. DEGs also have the advantage that they can be brought online and ramped up quickly.

The Hawaiian Electric Companies operate DEGs that range in size from 1 MW to 12.5 MW each.

Hawaiian Electric received the following information from Valley Power Systems Northwest. Valley Power has supplied diesel generation equipment to the Hawaiian Electric Companies and is familiar with their DEGs.[21] Diesel electric generators are generally very efficient in converting fuel energy into electric power. There are few options available for improving their energy efficiency. One option is to install a turbocharger if a unit is not already equipped with one. However, all of the DEGs

[21] Verbal communication between Dave Peterson of Valley Power Systems Northwest and Greg Narum of Hawaiian Electric, March 20, 2015.

covered by the Companies GHG Partnership already are equipped with turbochargers. Another option is to upgrade from 2-pass to 4-pass after coolers which can improve efficiency 1-3%. However, this may not be practical for all of Hawaiian Electric Companies' units because of their age and design. The benefit in terms of GHG emissions reduction would be small in any case, amounting to about 120 metric tons per year of CO_2e for a 2% efficiency improvement of a 1 MW generator.

An approach that would more substantially reduce GHG emissions would be to replace the existing diesel engine generators with newer, more efficient models. Hawaiian Electric estimates that heat rates could be improved 10% to 20%, depending on the unit, by replacing the Companies' larger DEGs with new units similar to those constructed at the Schofield Generating Station.[22] According to data Hawaiian Electric submitted to the Public Utilities Commission, the 2015 installed cost for new DEG capacity up to 100MW is $2970/KWh.[23] Assuming a 15% heat rate improvement averaged over all the units, the fuel cost savings would be about $280 per year per KW of capacity based on estimated 2015 fuel costs[24] and 8500 hours per year of operation. Therefore, it would require about 10 years for the energy savings to pay back the investment cost. That cost can only be justified if the existing unit is nearing the end of its useful life.

Summary of Potential Energy Efficiency Improvements

The Hawaiian Electric Companies operate their power generating units at energy efficiencies that are equivalent to or better than mainland averages for oil-fired generators despite constraints imposed by their isolated location. The Company has researched additional opportunities for improving efficiency beyond steps already taken but has not identified any that are operationally and economically justified given current system designs and needs.

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[22] Email from Robert Isler of Hawaiian Electric Generation Planning Department. June 22, 2015.

[23] *Hawaiian Electric Power Supply Improvement Plan*. Table F-11. Docket 2011-0206. August 2014.

[24] Ibid, Table F-5.