RESOLUTION NO. U-11199

A RESOLUTION authorizing adoption of the Washington State Department of Commerce Advisory Opinion WA2020-001 for renewable resources compliance for the Washington Energy Independence Act (I-937).

WHEREAS the City of Tacoma, Department of Public Utilities, Light Division (d.b.a. "Tacoma Power") completed a rebuild in December of 2011, of the turbines, transformers and wicket gate seals at Generators 51 and 52 located at the Mossyrock Dam Powerhouse, and

WHEREAS the Rebuild upgrades and the associated savings meet the requirements for a qualifying eligible renewal resources per RCW 19.285.040(2)(e) and WAC 194-37-130, and will assist in Tacoma Power's compliance with the Washington Energy Independence Act; and

WHEREAS a report updating and revising Tacoma Power's modeling to reflect actual stream flows for the most recent years and a request for an Advisory Opinion was submitted to the Washington Department of Commerce, per RCW 19.285.045 (2), on January 29, 2020, and

WHEREAS the Washington Department of Commerce advisory opinion process requires adequate information and a fee of $1,250 to perform a legal analysis and provide for a public comment period, and

WHEREAS as the Department of Commerce received no public comments, and the Department of Commerce agreed with Tacoma Power's modeling and issued its Advisory Opinion WA2020-001, on April 29, 2020, and

WHEREAS the savings from adopting this Advisory Opinion are estimated to save Tacoma Power approximately 44,800+ MWh plus an

additional 20% credit for using qualifying apprenticeship labor, for an estimated annual total of 53,760 MWh, which will assist in meeting the renewal standards for the Washington Energy Independence Act without purchasing additional renewable resources such as third-party renewable energy credits (valued at $2-$6/MWh), with an estimate savings of $107,520 to $322,560, and

WHEREAS a public hearing was conducted by the Board on September 23, 2020, as required by RCW 19.285.045 (2), Now, Therefore,

BE IT RESOLVED BY THE PUBLIC UTILITY BOARD OF THE CITY OF TACOMA:

That the Department of Commerce Advisory Opinion, in the form as on file with the Clerk, is adopted.

Approved as to form:

_____
Chair

/s/
Chief Deputy City Attorney

_____
Secretary

_____
Clerk

Adopted_____

TACOMA POWER | TACOMA WATER | TACOMA RAIL
TACOMA PUBLIC UTILITIES

Board Action Memorandum

TO:	Jackie Flowers, Director of Utilities
COPY:	Charleen Jacobs, Director and Board Offices
FROM:	**Clay Norris, Section Manager – Power Management**
MEETING DATE:	September 23, 2020
DATE:	September 2, 2020

SUMMARY:
Adopt by resolution and public hearing Washington State Department of Commerce Advisory Opinion WA2020-001 per RCW 19.285.045 (2) for renewable resources compliance with the Washington Energy Independence Act (also known as I937) involving approved engineering modeling for incremental hydro savings due to the 2011 rebuild at Mossyrock Dam/Powerhouse.

Per the advice of the Washington State Auditor's Office from our successful 2018 renewable compliance audit with the Washington Energy Independence Act RCW 19.285, our previous modeling of the Mossyrock Rebuild was dated (2010) and needed to reflect actual stream flows for the most recent years.

BACKGROUND: Provide information that is required to orient the Board. Provide context and frame the issue or topic.

In December 2011, Power completed a rebuild of the turbines, transformers and wicket gate seals at Generators 51 and 52 located at the Mossyrock Dam Powerhouse. These Rebuild upgrades and the associated savings qualify as a qualifying eligible renewable resource per RCW 19.285.040 (2) (e) and WAC 194-37-130 to meet portions of annual renewable resource compliance with Washington Energy Independence Act. The renewable savings plus apprenticeship labor credited were based on 2010 engineering modeling. Per the advice of the State Auditor's Office needed to reflect actual stream flows for the most recent years. A team of Ahlmahz Negash, Power Analyst with Power Management, Tyler Braun with Generation along with John Walkowiak, Conservation Operations Manager saw the opportunity update and revise the modeling report and submitted an Advisory Opinion to the Washington Department of Commerce per RCW 19.285.045 (2) on January 29, 2020.

Commerce's advisory opinion process requires adequate documentation, fee of $1,250 to perform a legal analysis and public comment period. There were no public comments regarding the Mossyrock Rebuild renewable energy savings. Commerce.agreed with Tacoma Power's modeling and issued Advisory Opinion WA2020-001 on April 29, 2020.

The savings from this Advisory Opinion are estimated to save Tacoma Power approximately 44,800+ MWh plus an additional 20% credit for using qualifying apprenticeship labor for an estimated annual total of 53,760 MWh to assist in meeting the renewable standards for the Washington Energy Independence Act without purchasing additional renewable resources such as third-party renewable energy credits (valued at $2-$6/MWh). Power Management estimates the annual cost savings to range from $107,520 to $322,560.

ARE THE EXPENDITURES AND REVENUES PLANNED AND BUDGETED? No.

IF THE EXPENSE IS NOT BUDGETED, PLEASE EXPLAIN HOW THEY ARE TO BE COVERED.
Explain how expenditures are to be covered and if budget modifications are required.

IF THE ACTION REQUESTED IS APPROVAL OF A CONTRACT, INCLUDE LANGUAGE IN RESOLUTION AUTHORIZING $200,000 INCREASE IN ADMINISTRATIVE AUTHORITY TO DIRECTOR? No.

ATTACHMENTS: Washington Department of Commerce – Energy Office Advisory Opinion WA2020-001

CONTACT:

John Walkowiak, Conservation Operations Manager (253) 316-6002 (cell) jwalkowiak@cityoftacoma.org
and Ahlmahz Negash, Power Analyst anegash@cityoftacoma.org
Provide supervisor's name. Ray Johnson, Assistant Power Section Manager II
Provide name of presenter at podium if different from primary contact.

Application 2020-001

Department of Commerce

Innovation is in our nature.

commerce.wa.gov/eia

Washington State
Energy Independence Act

Application for Advisory Opinion and Renewable Energy Facility (WREGIS) Certification

All information provided in this application or any supplemental or additional materials is subject to public disclosure.

FACILITY NAME: **Mossyrock Hydroelectric Project**
WREGIS Generating Unit ID (if already registered):

A separate Washington application is required for each generating unit with a separate WREGIS GU ID. Applicant must select Washington in WREGIS generating unit registration.

Section 1: Agency Action Requested

☒ Advisory Opinion and WREGIS Certification ☐ Advisory Opinion Only

Section 2: Applicant Information

Applicant Contact: **John Walkowiak** Title: **Cons Ops Manager**

Applicant Phone: **(253) 502-8534**

Applicant E-mail: **jwalkowiak@cityoftacoma.org**

Applicant Company Name: **Tacoma Power/Tacoma Public Utilities**

Company Address: **3628 South 35th Street**

City: **Tacoma** State/Province: **WA**

Zip Code: **98409-3192** Country: **USA**

Section 3: Facility Information

Facility Owner

Name of Facility Owner:
OR ☒ The Facility Owner is the same as the Applicant.

Address:

City/State/ZIP:

Contact Name, Phone, and Email:

Facility Identification and Location

Unit Name: **Mossyrock Dam**

Facility Name: **Cowltiz River Project**

Unit location (street address, legal description, or GPS coordinates):
WGS84 Coordinates 46 32'4"N, 122 25'43" W or 46.534444, -122.428611

City: **Mossyrock** County: **Lewis**

State/Province: **WA** Zip: **98564** Country: **USA**

Provide a description of the facility.

Mossyrock Dam completed by Tacoma Power in 1968 at a cost of $117.8 million and is Washington state's tallest dam at 606 feet above bedrock (or 365 feet above the Cowlitz Riverbed. The dam's double curvature concrete arch has three penstocks between 248 and 285 feet in length that extend down to the Mossyrock Powerhouse that contains two turbine/generators (Unit 51 and Unit 52) with nameplate rating of 382,000 kW. The Mosyrock Dam created 23.5 mile long Riffe Lake. The Mossyrock Rebuild project replaced/upgraded the the two 150,000 kW turbine generators, Transformers and wicket gate sealing for both Units that were 40+ years-old in 2010 and 2011 at a cost of $54 million.

Facility Identification Numbers

WREGIS Generating Unit ID: **Pending** Other External ID:

EIA Utility Code: EIA Plant Code:

Section 4: Facility Eligibility

A. Facility Profile

Nameplate Capacity (MW): **382**

If this value will change, please explain:

Commercial Operation Date (COD): **10** / **13** / **1968**

Is your facility considered repowered by WREGIS? ☐ Yes ☒ No

If yes, please explain:

B. Facility Fuel

Indicate each energy source used by the facility. For definitions, refer to RCW 19.285.030. For multi-fuel generating facilities indicate all fuels used.

☐	Wind	☐	Wave power
☐	Solar energy	☐	Ocean power
☐	Geothermal energy	☐	Tidal power
☐	Landfill gas	☐	Gas from sewage treatment facility
☐	Biomass energy (must complete Section 5)	☐	Biodiesel fuel (must complete Section 6)
☒	Water (must complete Section 7)	☐	Other (please specify):

Will the facility use any fossil fuel or other non-qualifying fuel? ☐ Yes ☒ No

- Type of fossil fuel or other non-qualifying fuel:
- Average annual amount of non-qualifying fuel used (percent of net heat input):

Section 5: Biomass Energy Supplement (complete only if "biomass energy" is checked in Section 4)

Allowed Fuel Sources. Indicate each source of biomass energy used by the facility.

☐	Organic by-products of pulping and the wood manufacturing process	☐	Food waste and food processing residuals
☐	Animal manure	☐	Liquors derived from algae
☐	Solid organic fuels from wood	☐	Dedicated energy crops
☐	Forest or field residues	☐	Yard waste
☐	Untreated wooden demolition or construction debris		

Prohibited Fuel Sources. The following materials will NOT be used as a source of biomass energy by the facility.

☐	Wood pieces that have been treated with chemical preservatives such as creosote, pentachlorophenol, or copper-chrome-arsenic	☐	Wood from old growth forests
		☐	Municipal solid waste

Legacy Biomass. The Washington Energy Independence Act allows a biomass energy facility commencing operation before March 31, 1999 to qualify as an eligible renewable resource in certain circumstances. Contact Commerce to obtain application requirements.

Section 6: Biodiesel Fuel Supplement (complete only if "biodiesel fuel" is checked in Section 4)

The biodiesel fuel used by the facility meets each of the identified conditions:

☐	The fuel (a) is a mono alkyl ester of long chain fatty acids derived from vegetable oils or animal fats for use in compression-ignition engines and (b) meets the requirements of the American society of testing and materials specification D 6751 in effect as of January 1, 2003.
☐	The fuel is NOT from crops raised on land cleared from old growth or first-growth forests where the clearing occurred after December 7, 2006.

Section 7: Water/Hydroelectric Power (complete only if "water" is checked in Section 4)

The facility uses water as a fuel in the following manner:

☒	**Incremental Hydro.** Incremental electricity produced as a result of efficiency improvements completed after March 31, 1999, to hydroelectric generation projects owned by a qualifying utility and located in the Pacific Northwest where the additional generation does not result in new water diversions or impoundments.	
	Date efficiency improvement completed: **12/1/2011**	
	Method of measuring incremental generation:	
	☐	Incremental generation is separately metered or measured.
	☒	Incremental generation is modeled each year based on actual stream flows.
	☐	Incremental generation is modeled as a fixed percentage of total generation. Fixed percentage: %
	☐	Incremental generation is modeled as a fixed generation amount. Fixed amount: megawatt-hours
	Note: If any box but the first is checked, the facility must register in WREGIS as a multi-fuel facility. Non-incremental generation will be classified as Large Hydro (LHN) and excluded from certificate creation.	
☐	**Canal or pipe.** Hydroelectric generation from a project completed after March 31, 1999, where the generation facility is located in irrigation pipes, irrigation canals, water pipes whose primary purpose is for conveyance of water for municipal use, and wastewater pipes located in Washington where the generation does not result in new water diversions or impoundments.	

Section 8: Eligibility for Washington Multipliers (Optional)

The facility qualifies for the following multipliers under the Washington Energy Independence Act:

☐	**Distributed Generation.** The facility has a generating capacity of 5 MW or less and is not part of any integrated cluster of facilities with an aggregate generating capacity of 5 MW or more.
☒	**Apprentice Labor.** The facility commenced operation after December 31, 2005 and in construction used an apprenticeship program approved by the Washington State Apprenticeship and Training Council.

NOTE: Commerce requests optional multiplier eligibility from facility owners for informational purposes only. Owners seeking certification of a facility as eligible for a multiplier should contact Commerce for application requirements.

Section 9: Reservation

The Washington Department of Commerce makes a determination of resource eligibility under the Washington Energy Independence Act based on the information provided by the applicant and does not independently verify that information. An applicant must promptly notify Commerce of any changes to the information submitted for certification that may affect the facility's eligibility. Commerce reserves the right to modify or withdraw a designation if it determines that the information supplied by the applicant was incomplete or inaccurate.

Section 10: Attestation

I declare that the information provided in this application and any supplemental forms and attachments are true and correct to the best of my knowledge, that the information contained in this submission is consistent with information on file with WREGIS unless otherwise indicated, that no information materially affecting the facility's eligibility has been withheld, and that I am authorized to file this submission on the facility owner's behalf.

Signature:

Date Signed: 1/29/2020

Authorized Officer/Agent: **Ray Johnson**

Officer Title and Company: **Power Section Assistant Manager II**

Name of Facility: **Tacoma Power - Mossyrock Dam**

Application Checklist for Submission

Applicants must select the Washington program administrator in the generating unit's WREGIS static data. Applicants should ensure that the following documents are provided:

1. Electronic copy of entire application, including a signed attestation page.
2. WREGIS "static data" if the facility is already registered in WREGIS. A printout of your generator account profile screen in WREGIS.
3. Optional project background documentation. Background documentation can be submitted or published in regulatory settings (FERC or state commission filings) or informal forums (websites, articles or factsheets).
4. Payment of advisory opinion fee of **$1,250**. A separate application and application fee are required for each generating unit. However, if a facility owner has multiple WREGIS generating unit IDs for a single facility and all the static characteristics of the facility (other than the generating capacity) are identical, it may request that Commerce treat the combined generating units as a single application. The owner must document at the time of application that all GU IDs are part of a single facility in a single location. If GU IDs are added later, a separate application will be required.

To submit your facility for certification, e-mail the application and any supplemental materials listed above to (wregis@commerce.wa.gov). Submit payment of the advisory opinion fee to:

Department of Commerce
Attn: State Energy Office
P.O. Box 42525
Olympia, WA 98504-2525

Commerce will post each application on its website. Applications are subject to a public comment period.

Advisory Opinion and WREGIS Certification (to be completed by Commerce)				
It is the opinion of the Washington Department of Commerce that the facility identified in this application meets the statutory legal standard for an eligible renewable resource as defined in RCW 19.285.030, based on the factors set out below The facility will be designated in WREGIS as an eligible renewable resource under the Washington Energy Independence Act:				
Facility Name:	Mossyrock Hydroelectric Project		WREGIS GU ID:	
[x]	The fuel source for the facility is identified in RCW 19.285.030 as renewable energy:			
	[ ] Wind		[ ] Wave, ocean, or tidal power	
	[ ] Solar energy		[ ] Gas from sewage treatment facilities	
	[ ] Geothermal energy		[ ] Biodiesel fuel	
	[ ] Landfill gas		[ ] Biomass energy	
	[x] Water (incremental efficiency hydro)		[ ] Water (pipe or canal)	
[x]	The facility commenced operation after March 31, 1999, as required by RCW 19.285.030.			
[x]	The facility is located in the Pacific Northwest, or the electricity from the facility is delivered into Washington state on a real-time basis without shaping, storage, or integration services, as required by RCW 19.285.030.			
Additional Provisions:	Incremental generation will be determined each year based on actual water flows and using the method provided in the engineering analysis provided as part of the application.			
Washington Certification Number:	WA2020-001			
	WASHINGTON DEPARTMENT OF COMMERCE			
	Michael Furze, by email 2020-04-29			
	Director or Designee Date			

Renewable Incremental Hydro

Mossyrock Rebuild

Mossyrock Dam

Tacoma Power/Tacoma Public Utilities

New Turbines, Transformers and Wicket Gate Sealing

Advisory Opinion Application/Documentation

TACOMA POWER | TACOMA WATER | TACOMA RAIL

TACOMA PUBLIC UTILITIES

January 30, 2020

30 JAN 2020

Renewable Incremental Hydro Report

Mossyrock Rebuild

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Overview/Summary

Tacoma Power, dba Light Division of Tacoma Public Utilities, is seeking Advisory Opinion approval of its engineering calculations/modeling for the incremental hydroelectric energy gains from the rebuild of our Unit 51 (2010) and Unit 52 (2011) turbines, generators and wicket gates sealing located at our Mossyrock Hydroelectric Project (Mossyrock) in Lewis County, WA. We believe that the incremental energy gains per year are eligible for Washington state's Renewable Portfolio Standard (RPS) per RCW 19.285.030 (12) (b). Tacoma Power proposes that Units 51 and 52 will be registered in the Western Renewable Energy Generation Information System (WREGIS) as a group and the incremental energy savings will be annually updated and reported as part of a proposed Qualified Reporting Entity (QRE) agreement and logged with WREGIS. The following report summarizes the engineering calculations/modeling developed and Tacoma Power's determination of incremental hydroelectric savings. Table 1 below summarizes our findings using actual 2018 Generation data.

Table 1: Mossyrock Rebuild Incremental Hydro – Summary Using 2018 Generation Data

Rebuild Action	Incremental Hydro Savings (MWh)
Turbine Rebuild	24,534
Transformer Replacement	1,200
Wicket Gate Sealing	19,099
Totals	44,833

Washington RPS Eligibility

Incremental hydroelectric energy savings are qualified under RCW 19.285.030 (12)(b), which allows incremental electricity produced as a result of efficiency improvements completed after March 31, 1999 to qualify as an eligible renewable resource. Tacoma Power is submitting this Advisory Opinion report to register the incremental hydroelectric efficiency gains in WREGIS accordance with WAC 194-37-130 (3) (c) (ii) Method One – actual incremental generation.

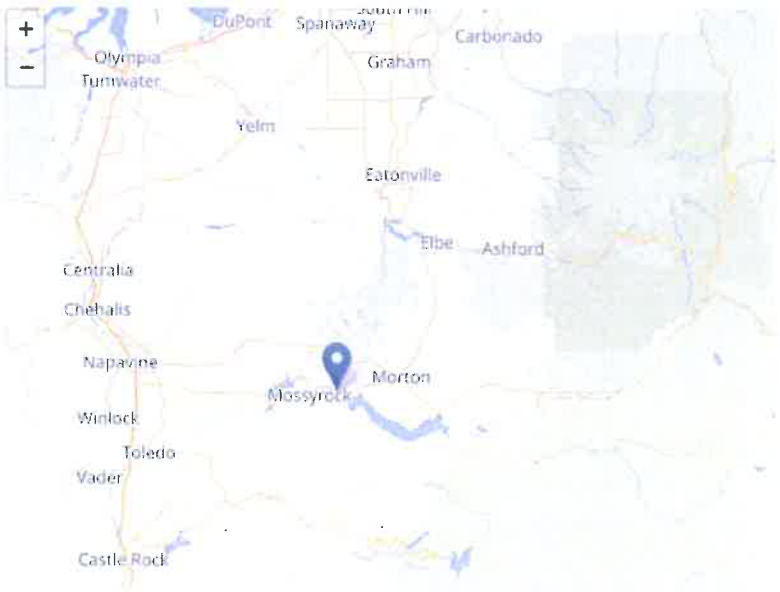
Project Owner

Project Owner	**Tacoma Power – dba Light Division Tacoma Public Utilities**
Street Address	**3628 South 35th Street, Tacoma WA 98409-3192**
Mailing Address	**P.O. Box 11007, Tacoma, WA 98411-0007**
Project Representatives	**John Walkowiak, Conservation Operations Manager** **Ahlmahz Negash, Power Analyst** **Tyler Braun, PE, Power Engineer III**
Phone	**(253) 502-8534; (253) 502-8093; (253) 502-8658**
Email	jwalkowiak@cityoftacoma.org; anegash@cityoftacoma.org; tbraun@cityoftacoma.org
Fax	**(253) 502-8572**
Website	www.mytpu.org

Project Location and Site Description

The Mossyrock Dam and Hydroelectric facility is part of Tacoma Power's Cowlitz River Project located in eastern Lewis County, WA. Mossyrock Dam was completed by Tacoma Power in 1968 at a cost of $117.8 million and is Washington State's tallest dam at 606 feet above bedrock (or 365 feet above the Cowlitz Riverbed). The dam created 23.5-mile-long Riffe Lake. The dam's double-curvature concrete arch has three penstocks between 248 and 285 feet in length that extend down to the powerhouse. The powerhouse contains two turbine generators (Unit 51 and Unit 52) with a combined nameplate rating of 382,000 kW.

Figure 1: Location of the Mossyrock Dam and Hydroelectric Project



The $50 million Mossyrock Rebuild project began in March 2008, replacing and/or upgrading the original, 40-year-old turbines, generators, exciters, plant controls, transformers and wicket gate end seals for Units 51 (completed 2010) and Unit 52 (completed in 2011) and increasing total capacity by 70 MW with peak overall energy conversion efficiency near 95%.

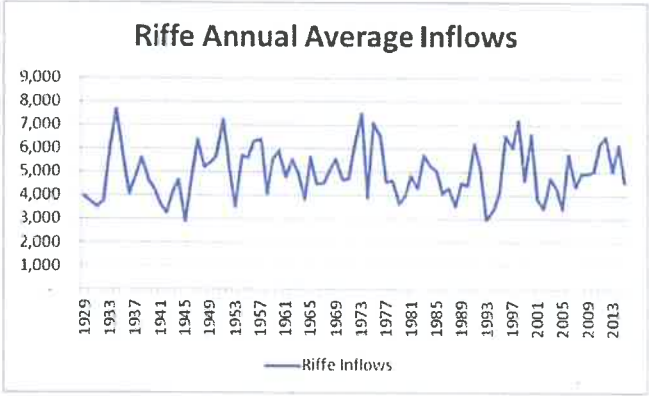
Figure 2: Mossyrock Dam Photo, October 2019

Engineering Review

Mossyrock Rebuild Turbine Calculations/Modeling

Because it is not possible to directly measure the incremental hydro generation from our Mossyrock turbine rebuild project, Tacoma Power originally utilized a Vista LT hydro optimization model (Vista) for RPS reporting years 2010-2014. The Vista model utilized historical inflows for an 75-year period from 1929-2003, Tacoma Power developed "Content Tables" for reservoir water elevations for the range of turbine operations within 621-780 ft. and a set of I/O curves that reflected unit characteristics before (pre-) and after (post-) rebuild. Starting in 2016, Tacoma Power updated the historical Riffe Lake inflows for the period 2004 through 2018 (Figure 3) in order to meet compliance requirements that the most readily available stream flow records be used to provide annual incremental hydro savings per WAC 194-37-130 3 (c) (ii) or (iii).

Figure 3: Riffe Lake Inflows, 1929-2018



Tacoma Power no longer utilizes the Vista model. Since the amount of efficiency improvement will vary from year to year because of changing reservoir inflows and operating conditions, we plan to provide actual annual generation savings utilizing Method One of WAC 194-37-130 (3) (c) (i), using the following engineering model (Equation 1) of hydropower generation, P, as a function of turbine efficiency, η_t, generator efficiency, η_g, flow through the turbine, Q, and net head, h_{net}, to calculate pre- and post-rebuild turbine efficiency. To show validity of Equation 1, we used it to calculate an average percentage incremental generation over a historic period and assumed similar operating conditions both before (pre-) and after (post-) rebuild.

$$P = \eta_t \eta_g \left(\frac{1000kg}{m^3}\right)\left(\frac{9.81m}{s^2}\right)\frac{h_{net}}{\frac{3.28ft}{m}}\frac{Q}{\left(\frac{3.28ft}{m}\right)^3}\left(\frac{10^{-6}MW}{W}\right) \quad \text{(Equation 1)}$$

Historic Calculation Period:

The historic calculation period spanned 2011 – 2018. These years represent a range of wet, dry and average water conditions as well as a significant change in operations for the Mossyrock project. Starting in 2016, the United States Geological Survey (USGS) revised its earthquake predictions for the Cowlitz River Basin. To protect public safety, Tacoma Power began holding Mossyrock's Riffe Lake

maximum elevation approximately 30 feet below full. This lower lake elevation is likely to remain in effect at least into the next decade. The new lower maximum lake elevation is of particular significance given that the efficiency upgrade for Mossyrock's Unit 51 was designed to reach maximum turbine efficiency at lower lake elevation.

Data Requirements:

The data required for this analysis involved:

1. Post-Rebuild Generation and Elevation were acquired actual hourly measurements of generation and lake elevation for each Mossyrock Project unit (Unit 51 and Unit 52) during the post-rebuild historic period
2. Post-Rebuild Turbine Efficiency Tables were created using field test measurements of each unit's turbine efficiency after the rebuild, at various lake levels and various levels of flow through the turbines.
3. Pre-Rebuild Turbine Efficiency Tables were created using field test measurements of each unit's turbine efficiency prior to the rebuild, at various lake levels and various levels of flow through the turbines.

Analysis – Amount of Incremental Generation

Using Equation 1, field test measurements of unit efficiency were used to create lookup tables for post-rebuild (Table 2) and pre-rebuild (Table 3) flow, generation, and elevation sets. Given any feasible set of generation and lake level, the corresponding flows through the unit can be determined in the look-up tables; alternatively, given a set of flow and elevation, the corresponding powers could be determined in the post-rebuild lookup table. It is worth noting here that the efficiency upgrade changed the feasible operating range of the turbines (in terms of elevation and flow), as illustrated in Figures 4 and 5.

The following describes the 6-step methodology used to calculate the amount of incremental hydro generation of the Mossyrock upgrade using the data described above:

1. Created "Post-Rebuild Turbine Efficiency Tables" (Table 2) for New Units 51 and 52 using new efficiency curves (Figures 4 & 5) based on field testing conducted post-rebuild (table row = power output in MW, table column = lake elevation in ft).

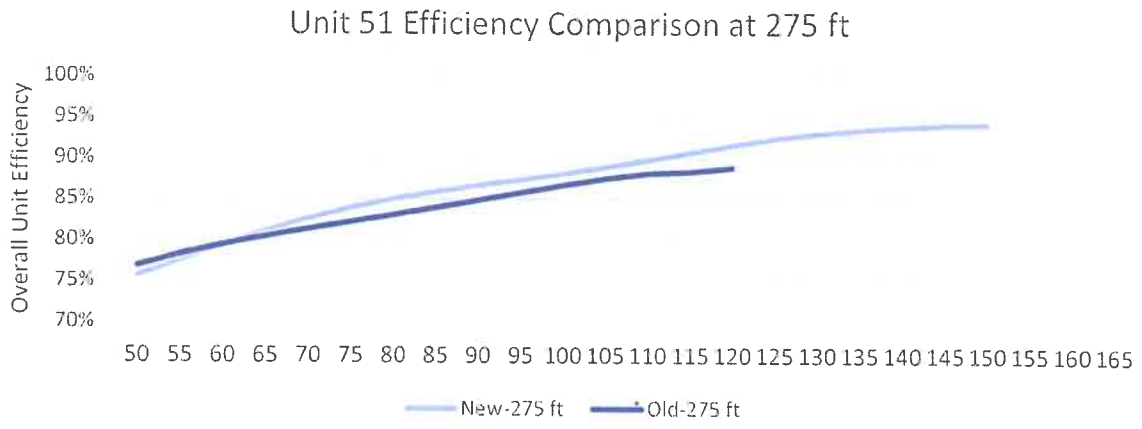
Table 2: Step 1 – Post-Rebuild Flow Lookup Table (Flow, "cfs")

	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	778.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1061	1056	1055	1054	1055	1057	1060	1059	1049	1029	1005	977	952	925	892	854	827
10	1354	1328	1311	1296	1286	1274	1263	1250	1231	1207	1183	1164	1144	1124	1103	1084	1067
15	1553	1521	1488	1461	1444	1429	1411	1393	1368	1341	1320	1300	1282	1272	1263	1245	1226
20	1726	1689	1652	1617	1592	1572	1552	1528	1500	1473	1449	1432	1419	1415	1406	1386	1370
25	1897	1851	1815	1783	1751	1724	1700	1670	1639	1612	1589	1579	1572	1562	1545	1526	1512
30	2077	2020	1982	1955	1928	1900	1871	1838	1805	1779	1761	1749	1734	1712	1691	1676	1664
35	2270	2206	2161	2134	2117	2103	2081	2049	2018	1992	1968	1937	1908	1878	1855	1832	1817
40	2479	2409	2364	2336	2317	2299	2276	2250	2223	2197	2171	2143	2111	2072	2031	2001	1985

45	2711	2628	2574	2538	2511	2495	2491	2464	2435	2404	2368	2333	2296	2259	2221	2184	2162
50	2935	2839	2773	2732	2708	2694	2697	2682	2653	2618	2571	2526	2480	2437	2397	2361	2341
55	3145	3047	2983	2933	2903	2888	2884	2871	2843	2809	2766	2717	2668	2618	2571	2529	2507
60	3356	3256	3184	3131	3090	3070	3061	3046	3019	2990	2947	2898	2845	2792	2740	2696	2672
65	3550	3454	3382	3326	3282	3253	3234	3215	3190	3160	3120	3071	3017	2962	2913	2865	2838
70	3747	3654	3584	3529	3482	3444	3410	3382	3358	3334	3298	3248	3195	3139	3083	3033	3005
75	3949	3857	3790	3734	3685	3639	3596	3557	3526	3506	3473	3424	3370	3312	3257	3208	3179
80	4156	4072	4000	3940	3888	3837	3785	3737	3696	3664	3635	3596	3546	3486	3428	3377	3349
85	4363	4285	4218	4154	4094	4035	3976	3918	3863	3820	3786	3747	3702	3652	3602	3551	3518
90	4577	4504	4436	4369	4302	4236	4169	4099	4033	3980	3938	3899	3859	3814	3766	3717	3681
95	4795	4725	4659	4592	4516	4440	4361	4283	4211	4152	4102	4058	4015	3973	3928	3877	3841
100	5016	4947	4876	4801	4725	4645	4558	4474	4399	4335	4280	4232	4185	4137	4088	4037	4000
105	5238	5163	5090	5014	4931	4846	4759	4675	4599	4531	4468	4409	4355	4305	4256	4203	4165
110	5462	5378	5297	5213	5127	5041	4956	4872	4795	4723	4655	4592	4534	4480	4427	4373	4335
115	5686	5593	5500	5408	5318	5233	5150	5068	4989	4917	4848	4779	4716	4657	4601	4544	4504
120	5907	5803	5701	5602	5511	5425	5340	5257	5178	5106	5037	4970	4905	4839	4778	4718	4675
125	6131	6016	5904	5802	5707	5618	5531	5445	5364	5290	5220	5152	5086	5022	4957	4892	4845
130	6361	6236	6120	6011	5909	5811	5720	5630	5545	5468	5398	5330	5264	5199	5132	5063	5014
135	6603	6472	6348	6228	6116	6012	5913	5818	5730	5649	5576	5507	5440	5373	5303	5232	5179
140	6863	6719	6584	6457	6337	6223	6114	6011	5916	5831	5755	5684	5614	5547	5476	5400	5344
145	7136	6980	6834	6696	6565	6441	6322	6208	6105	6014	5935	5861	5791	5721	5646	5567	5508
150		7256	7096	6946	6805	6669	6539	6417	6307	6208	6122	6043	5969	5892	5815	5733	5673
155				7212	7057	6909	6769	6638	6519	6410	6316	6229	6147	6067	5987	5901	5838
160					7323	7162	7011	6869	6740	6623	6519	6423	6334	6249	6162	6073	6007
165						7430	7265	7111	6972	6847	6732	6627	6529	6436	6344	6251	6185
170							7532	7367	7218	7083	6957	6841	6732	6630	6532	6435	6365
175								7637	7477	7330	7192	7064	6945	6833	6726	6623	6551
180									7749	7588	7438	7298	7168	7045	6929	6819	6742
185										7860	7696	7544	7401	7268	7142	7022	6941
190												7802	7647	7502	7365	7236	7148
195													7906	7748	7599	7459	7365
200														8007	7846	7694	7592
205																7941	7831
210																	8083

Efficiency Curves Pre and Post Rebuild (based on actual field tests)

Figure 4: Unit 51 Efficiency Curve Comparison



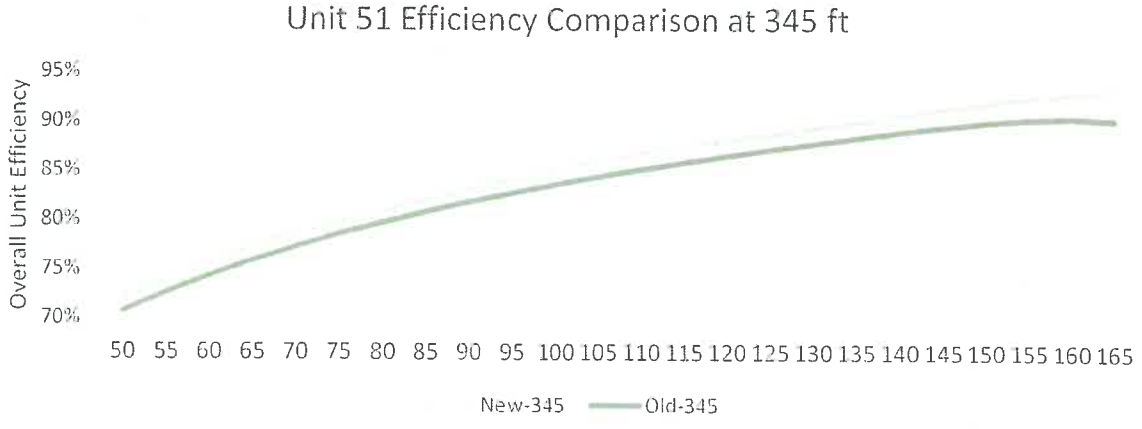
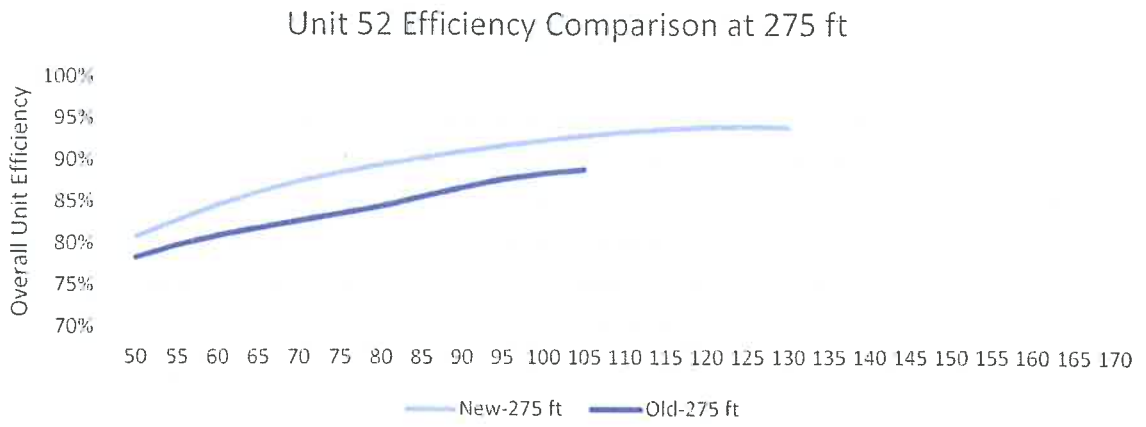
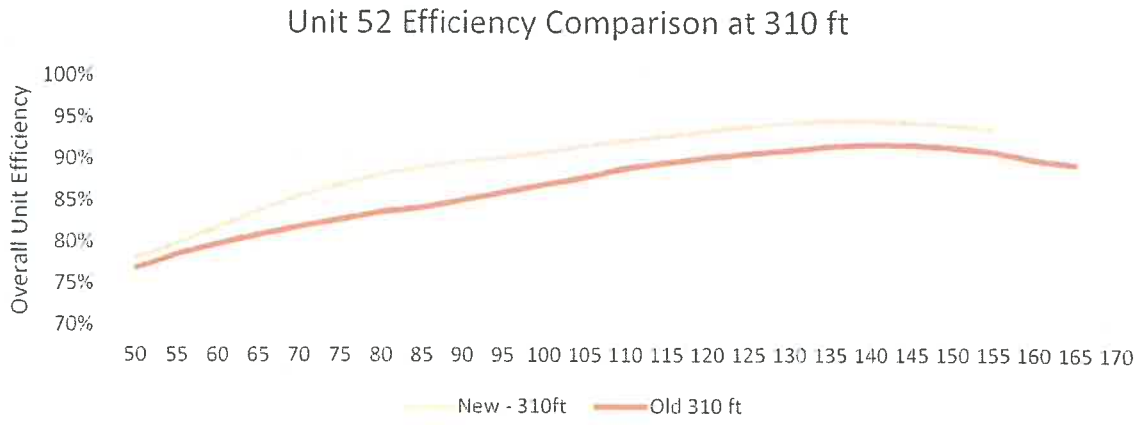
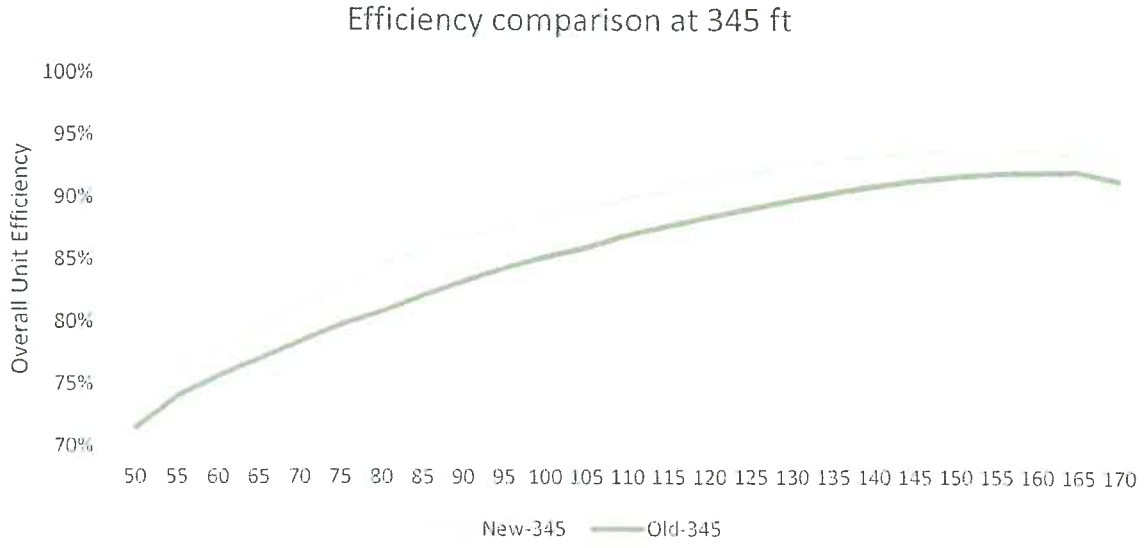


Figure 5: Unit 52 Efficiency Curve Comparison







2. Created "Pre-Rebuild Turbine Efficiency Tables" (Table 3) for old Units 51 and 52 using old efficiency curves (Figures 4 & 5) based on field testing just prior to rebuild (table row = flow in cfs, table column = lake elevation in ft.).

Table 3: Step 2 – Pre-Rebuild Power Lookup Table (Power, "MW")

	695	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780
0																		
250																		
500																		
750																		
1000																		
1250		11	12	12	12	13	13	13	13	13	13	14	14	15	15	15	16	
1500		18	18	19	19	20	20	20	21	21	21	22	22	22	22	23	23	
1750		23	25	25	26	27	27	28	28	28	29	29	29	30	30	30	30	
2000		27	31	32	32	33	33	33	34	35	35	36	36	37	37	37	38	
2250		30	33	37	39	40	40	41	41	42	43	43	43	44	44	44	45	
2500		42	43	44	45	45	46	47	48	48	49	50	50	51	51	52	52	
2750		47	48	49	50	51	52	53	54	55	56	56	57	57	58	59	59	
3000		53	54	55	56	57	58	59	60	61	62	63	63	64	65	66	67	
3250		58	59	61	62	63	64	65	66	67	68	69	70	71	72	73	74	
3500		63	65	66	67	69	70	71	72	73	74	76	77	78	79	80	81	
3750		69	70	72	73	74	76	77	78	80	81	82	84	85	86	87	89	
4000		74	76	77	79	80	82	83	85	86	88	89	90	92	93	95	96	
4250		80	81	83	85	86	88	90	91	93	94	96	97	99	101	102	104	
4500		86	87	89	91	93	95	96	98	100	101	103	105	106	108	110	111	
4750		92	94	96	97	99	101	103	105	107	108	110	112	114	115	117	119	
5000		98	100	102	104	106	108	110	112	114	116	117	119	121	123	125	127	
5250		104	106	108	110	112	114	116	118	121	123	125	127	129	131	132	134	
5500		110	112	114	116	118	120	123	125	127	129	131	133	135	138	140	142	
5750		115	117	119	121	123	126	128	131	133	136	138	141	143	145	147	150	
6000			121	124	127	129	132	135	137	140	142	145	147	150	152	155	157	
6250					132	135	138	141	143	146	148	151	153	156	158	161	163	
6500							143	146	149	151	154	156	159	162	164			
6750								150	153	156	159	162	164					
7000										161	164							
7250																		
7500																		
7750																		
8000																		
8250																		
8500																		

3. Collected actual Post-Rebuild Generation and Elevation data (Table 4) for years 2011-2018.

Table 4: Step 3 – Sample Post-Rebuild Generation and Elevation Data

YEAR	MONTH	DAY	HOUR	ELEVATION (FT)	POWER - U51 (MWH)	POWER - U52 (MWH)
2011	1	1	0	737	9	0
2011	1	1	1	737	0	0
2011	1	1	2	737	0	0
2011	1	1	3	737	0	0
2011	1	1	4	737	0	28
2011	1	1	5	737	0	109
2011	1	1	6	737	0	110
2011	1	1	7	737	52	112
2011	1	1	8	737	98	101
2011	1	1	9	737	100	93
2011	1	1	10	737	100	89
2011	1	1	11	737	77	98
2011	1	1	12	737	0	104
2011	1	1	13	737	0	89
2011	1	1	14	737	0	102
2011	1	1	15	737	0	101
2011	1	1	16	737	101	91
2011	1	1	17	737	111	90
2011	1	1	18	737	135	90
2011	1	1	19	737	151	90
2011	1	1	20	737	160	90
2011	1	1	21	737	153	90
2011	1	1	22	736	117	48
2011	1	1	23	736	120	0

4. Determined hourly post-rebuild flow (Table 5) through each unit: for each set of hourly, post-rebuild power and elevation data points, look up the corresponding flow in the "Post-Rebuild Flow Table". Exceptions:
    i. If post-rebuild power is 0, then set flow to 0.
    ii. If post-rebuild power is outside the feasible range of power in the "Post-Rebuild Flow Table", then set power to zero AND set flow to 0.
    iii. If post-rebuild elevation is outside the feasible range of elevation in the "New Flow Table", then set power to 0 AND set flow to 0.
5. Determined pre-rebuild power for Units 51 and 52: With flow and elevation sets from Step 4, find corresponding pre-rebuild power using the "Pre-Rebuild Power Table" (Table 5). Exceptions:
    i. If flow is 0, then set pre-rebuild power to 0.
    ii. If flow is outside the range of the flows in the "Pre-Rebuild Power Table", then set pre-rebuild power to 0.

iii. If elevation is outside the range of the elevations in the "Pre-Rebuild Power Table", then set pre-rebuild power to 0.

6. For each year, calculated average annual percentage of incremental hydro as the difference in post-rebuild power and pre-rebuild power divided by pre-rebuild power.

Table 5: Steps 4-6 – Post-Rebuild and Pre-Rebuild Power, Elevation, and Flow Delta Calculations for Sample 24-Hour Period

Step 4: Given Power and Elevation, look up Flow		**Step 5: Given Flow, look up Power**		**Step 6: Calculate Difference**	
Flow-U51	Flow-U52	Power-U51	Power-U52	Delta-U51	Delta-U52
1145	0	13.1	0	-4.1	0
0	0	0.0	0	0.0	0
0	0	0.0	0	0.0	0
0	0	0.0	0	0.0	0
0	1595	0.0	24.9405	0.0	3.0595
0	4529.5	0.0	103.0615	0.0	5.9385
0	4720.5	0.0	103.0615	0.0	6.9385
2762.5	4720.5	57.4	103.0615	-5.4	8.9385
4341	4342	95.4	96.2925	2.6	4.7075
4536.5	3952	102.3	82.9045	-2.3	10.0955
4536.5	3749.5	102.3	76.6205	-2.3	12.3795
3626.5	4152	75.9	89.4775	1.1	8.5225
0	4342	0.0	96.2925	0.0	7.7075
0	3749.5	0.0	76.6205	0.0	12.3795
0	4342	0.0	96.2925	0.0	5.7075
0	4342	0.0	96.2925	0.0	4.7075
4536.5	3952	102.3	82.9045	-1.3	8.0955
4930.5	3952	109.2	82.9045	1.8	7.0955
5867	3952	135.3	82.9045	-0.3	7.0955
6468	3952	147.2	82.9045	3.8	7.0955
6920.5	3952	157.0	82.9045	3.0	7.0955
6468	3952	147.2	82.9045	5.8	7.0955
5123	2318.5	116.1	45.355	0.9	2.645
5310.5	0	122.6	0	-2.6	0

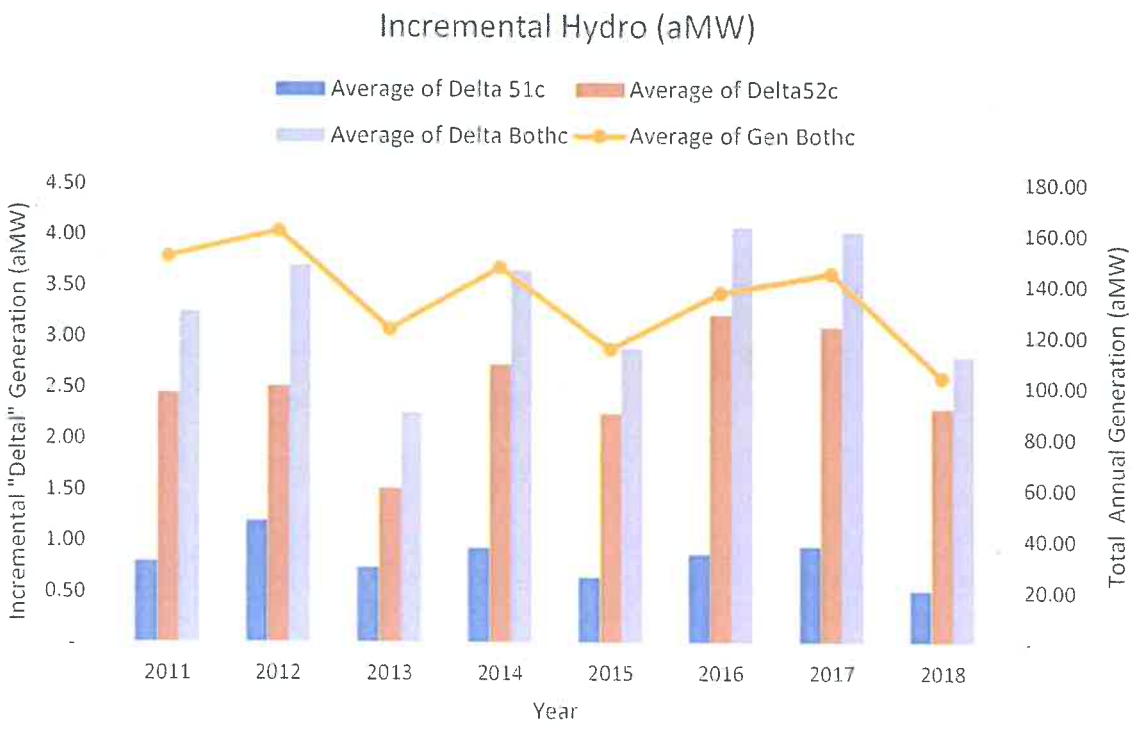
Table 6 and Figure 6 below summarize the average annual energy gains for the Mossyrock Turbine Rebuild for water years 2011-2018.

Beginning on January 1, 2020, Tacoma Power plans to calculate actual annual incremental energy gain (MWh) for the Mossyrock Turbine Rebuild for Washington RPS Method One compliance using Equation 1 and the associated tables and figures described for future RPS compliance periods.

Table 6: Calculated Average Annual Percentage/Savings of Incremental Hydro for Mossyrock Turbine Rebuild Units 51 & 52 Combined, 2011-2018

	Incremental Generation (%)	Incremental Generation (aMW)	Incremental Generation (MWH)
2011	2.14%	3.24	28,389
2012	2.29%	3.70	32,391
2013	1.83%	2.25	19,690
2014	2.48%	3.65	31,973
2015	2.50%	2.88	25,239
2016	2.97%	4.08	35,703
2017	2.79%	4.03	35,305
2018	2.70%	2.80	24,534
AVERAGE:	**2.46%**	**3.33**	**29,153**

Figure 6: Results – Annual Incremental Hydro vs. Annual Generation



Engineering Review:

Mossyrock Rebuild Transformers Calculations/Modeling

During the Mossyrock Turbine Rebuild for Unit 51 (2010) and Unit 52 (2011), Tacoma Power replaced each of the two original (1967-68), Allis-Chalmers generator step-up (GSU) transformers with a bank of three one-phase transformers rated at 225 MVA in total.

We calculated the incremental hydro generation due to the transformer replacement based on the annual difference in losses of the new transformer banks and old transformer banks. This calculation required transformer performance testing of no-load and load losses (Table 7) as well as actual Unit 51 and Unit 52 generation data from 2011-2018. For each transformer bank (and for each year of generation data), we performed the following calculation:

1. Determined the "Loss Difference Vector", the difference between old and new transformer losses as a function of discrete transformer loading levels using measured no-load loss and loss at rated MVA (see Equation 2 and Table 7).

Table 7: Measured "No-Load Losses" and "Losses at Rated MVA" per Transformer (Three Transformers for Each of the Two Generating Units)

		Rated Power (MVA)	No Load Loss (kW)	Losses @ Rated MVA (kW)
U-51	Old Transformer	54.7	45.4	216.3
	New Transformer	75.0	47.5	206.7
U-52	Old Transformer	54.7	46.0	213.2
	New Transformer	75.0	47.3	205.5

$$Loss\ Difference\ Vector_{MVA} = Loss_{No\ Load} + Loss_{rated\ MVA}\left(\frac{MVA}{rated\ MVA}\right)^2 \qquad (Equation\ 2)$$

Figure 7: Unit 51 Loss Difference Vector

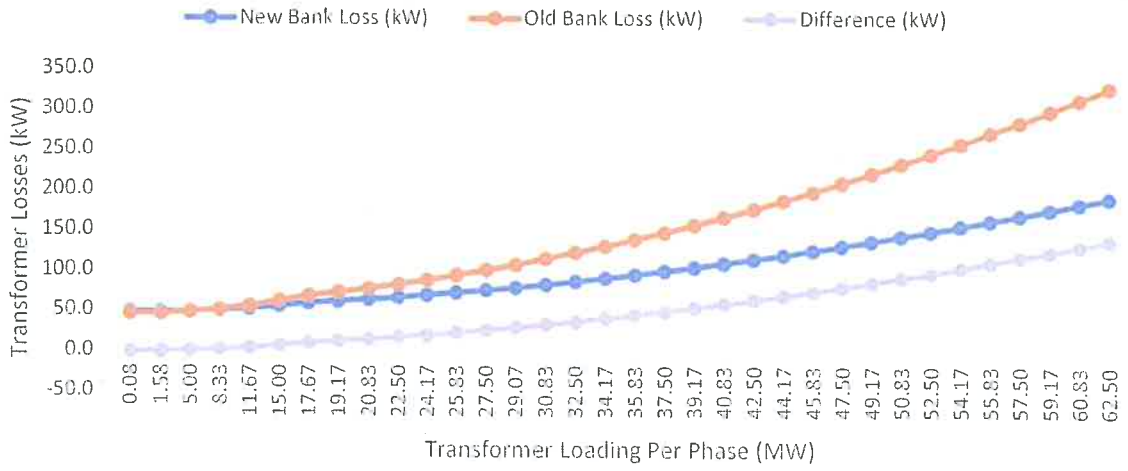


Figure 7: Transformer Losses as a Function of Transformer Loading Level (per Phase)

2. Determine the "Annual Operation Vector", the annual histogram of actual hourly generation data to determine the number of hours of operation in the aforementioned discrete transformer loading levels.

Figure 8: Unit 51 Operation Summary (2018)

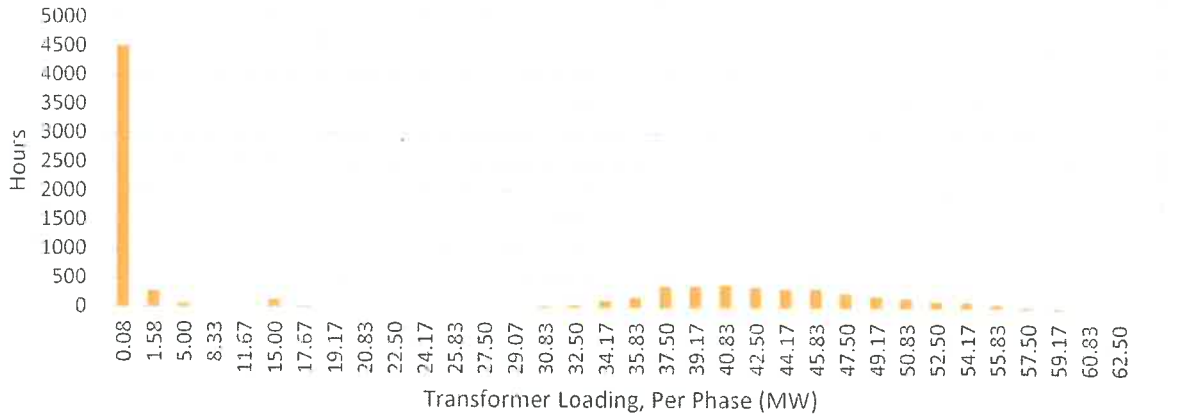


Figure 8: Generation Operation Summary for Unit 51 (for Year 2018)

3. Determine the annual incremental generation, the dot product[1] of "Annual Operation Vector" and "Loss Difference Vector" multiplied by three to get the annual incremental hydro RECs for the three transformer phases.

Figure 9: Unit 51 Annual Operation Vector (2018)

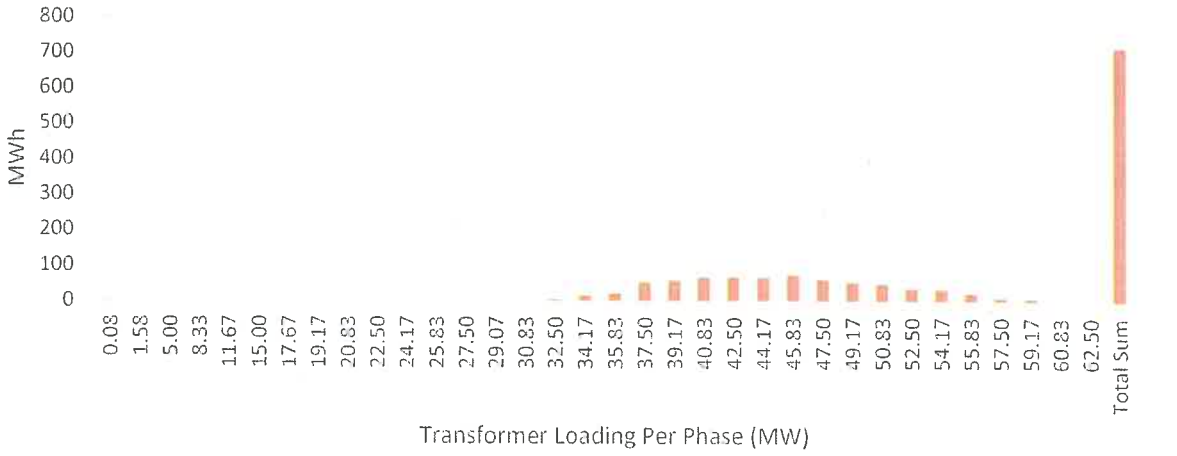


Figure 9. Histogram (Annual Operation Vector) for Unit 51 (for Year 2018)

[1] The dot product is the sum of the products of two vectors ("sum product" formula in MS Excel).

Tables 8 through 11 below summarize the data used for calculating incremental hydro generation for Units 51 & 52. Figures 7 through 9 above illustrate this calculation for Unit 51 and for the year 2018.

Table 8: Operations Summary for Unit 51, 2011-2018

Unit 51 History								
Generation	2018	2017	2016	2015	2014	2013	2012	2011
MW	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
0-.5	4513	3030	3429	4535	3186	2891	2537	4166
0-10	286	291	216	286	291	498	342	302
10-20	67	55	37	72	88	94	98	125
20-30	15	12	4	11	11	14	13	25
30-40	9	6	7	6	3	2	3	9
40-50	136	5	3	6	5	3	3	6
51-55	28	1	0	1	0	1	3	4
56-60	9	1	1	3	0	2	2	2
60-65	7	3	1	3	0	2	0	3
66-70	11	1	6	7	0	4	4	8
71-75	8	0	4	19	0	3	1	5
76-80	11	2	4	26	3	3	1	3
81-85	3	6	1	24	6	16	11	6
86-90	11	11	14	23	4	36	10	10
91-95	24	14	13	13	39	105	29	13
96-100	47	30	12	41	80	158	78	72
101-105	129	231	242	136	163	247	135	127
106-110	180	284	302	182	223	281	175	126
111-115	376	373	366	168	259	325	265	160
116-120	380	405	457	229	278	399	319	157
121-125	399	448	468	243	341	403	387	200
126-130	367	488	513	255	400	379	409	214
131-135	338	512	500	240	337	386	390	265
136-140	340	493	467	262	374	376	455	301
141-145	267	425	412	243	353	348	463	327
146-150	219	385	373	239	375	325	449	292
151-155	186	313	255	223	291	316	401	303
156-160	134	304	188	222	298	232	403	304
161-165	117	255	172	199	287	238	442	264
166-170	73	147	151	168	209	169	299	218
171-175	33	108	68	120	194	157	212	205
176-180	26	88	46	83	199	97	152	120
181-185	9	28	34	47	160	97	114	93
186-200	1	4	17	420	276	144	149	324
200-210	0	0	0	4	26	8	29	0
210-220	0	0	0	0	0	0	0	0
	8759	8759	8783	8759	8759	8759	8783	8759

Table 9: Unit 51 Transformer Improvement

Mossyrock Xfmr Bank Losses Value Calculation				Old Transformer Tests (per phase): U51			New Transfonner Tests (per phase): U51	
			New Bank	54.70	Rated Power (MVA)		75.00	Rated Power (MVA)
			Old Bank	45.40	No Load Loss (kW)		47.00	No Load Loss (kW)
				216.26	Load Losses @ Rated MVA (kW)		206.60	Load Losses @ Rated MVA (kW)
Generation MW	Load Avg	Each Phase Xfmr Load	Each (1 of 3) New Bank Loss	Each (1 of 3) Old Bank Loss	Difference	Three Xfmrs		
			New Bank Loss	Old Bank Loss				
0-.5	0.25	0.08	47.0	45.4	-1.6	-4.799		
.5-10	4.75	1.58	47.1	45.6	-1.5	-4.533		
10-20	15	5.00	47.9	47.2	-0.7	-2.134		
20-30	25	8.33	49.6	50.4	0.9	2.6061		
30-40	35	11.67	52.0	55.2	3.2	9.7159		
40-50	45	15.00	55.3	61.7	6.4	19.196		
51-55	53	17.67	58.5	68.0	9.5	28.486		
55-60	57.5	19.17	60.5	72.0	11.5	34.378		
60-65	62.5	20.83	62.9	76.8	13.8	41.488		
65-70	67.5	22.50	65.6	82.0	16.4	49.19		
70-75	72.5	24.17	68.5	87.6	19.2	57.485		
75-80	77.5	25.83	71.5	93.6	22.1	66.372		
80-85	82.5	27.50	74.8	100.1	25.3	75.852		
85-90	87.2	29.07	78.0	106.5	28.4	85.303		
90-95	92.5	30.83	81.9	114.1	32.2	96.589		
95-100	97.5	32.50	85.8	121.7	35.9	107.85		
100-105	102.5	34.17	89.9	129.8	39.9	119.7		
105-110	107.5	35.83	94.2	138.2	44.0	132.14		
110-115	112.5	37.50	98.6	147.0	48.4	145.17		
115-120	117.5	39.17	103.3	156.3	52.9	158.8		
120-125	122.5	40.83	108.2	165.9	57.7	173.02		
125-130	127.5	42.50	113.3	176.0	62.6	187.83		
130-135	132.5	44.17	118.6	186.4	67.7	203.24		
135-140	137.5	45.83	124.2	197.2	73.1	219.23		
140-145	142.5	47.50	129.9	208.5	78.6	235.82		
145-150	147.5	49.17	135.8	220.1	84.3	253.01		
150-155	152.5	50.83	141.9	232.2	90.3	270.78		
155-160	157.5	52.50	148.2	244.6	96.4	289.15		
160-165	162.5	54.17	154.8	257.5	102.7	308.11		
165-170	167.5	55.83	161.5	270.7	109.2	327.66		
170-175	172.5	57.50	168.4	284.4	115.9	347.8		
175-180	177.5	59.17	175.6	298.4	122.8	368.54		
180-185	182.5	60.83	182.9	312.9	130.0	389.87		

Table 10: Operations Summary for Unit 52, 2011-2018

Unit 52 HIstory								
Generation	2018	2017	2016	2015	2014	2013	2012	2011
MW	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
0-.5	4012	3308	3365	4527	3767	5362	3647	3028
0-10	489	316	354	276	258	278	276	276
10-20	113	129	109	59	93	118	135	103
20-30	71	44	28	15	14	38	19	35
30-40	111	16	11	9	14	11	5	11
40-50	51	21	11	7	3	9	2	18
51-55	16	5	4	4	3	4	0	5
56-60	12	11	7	5	6	0	3	4
60-65	11	7	5	8	8	4	1	5
66-70	14	13	9	9	14	6	2	4
71-75	27	9	17	10	15	5	5	17
76-80	46	26	30	63	12	14	12	26
81-85	152	43	67	68	29	11	16	59
86-90	267	99	394	245	219	22	16	107
91-95	634	667	657	318	283	61	124	136
96-100	460	545	571	322	325	167	158	136
101-105	411	658	669	313	429	223	340	183
106-110	406	531	516	267	348	207	290	183
111-115	369	524	495	260	412	258	433	199
116-120	331	429	366	280	342	265	382	232
121-125	310	404	339	260	356	261	448	271
126-130	198	335	221	240	307	261	398	287
131-135	120	221	198	203	337	318	465	390
136-140	70	167	136	197	280	222	401	349
141-145	33	110	92	175	279	261	389	515
146-150	14	64	49	110	159	138	271	358
151-155	11	37	36	82	179	136	204	651
156-160	0	20	15	65	121	48	118	216
161-165	0	0	12	189	90	30	51	201
166-170	0	0	0	173	46	12	83	342
171-175	0	0	0	0	11	9	83	211
176-180	0	0	0	0	0	0	6	201
181-185	0	0	0	0	0	0	0	0
186-200	0	0	0	0	0	0	0	0
200-210	0	0	0	0	0	0	0	0
210-220	0	0	0	0	0	0	0	0
	8759	8759	8783	8759	8759	8759	8783	8759

Table 11: Unit 52 Transformer Improvement

Mossyrock Xfmr Bank Losses Value Calculation	Old Transformer Tests (per phase): U52	New Transformer Tests (per phase): U52
	54.70 Rated Power (MVA)	75.00 Rated Power (MVA)
	46.00 No Load Loss (kWh)	47.30 No Load Loss (kWh)
	213.00 Load Losses @ Rated MVA (kWh)	205.50 Load Losses @ Rated MVA (kWh)

Generation MW	Load Avg	Each Xfmr Load	Each (1 of 3) New Bank Loss New Bank Loss	Each (1 of 3) Old Bank Loss Old Bank Loss	Difference	Three Xfmrs
0-5	0.25	0.08	47.3	46.0	-1.3	-3.899
5-10	4.75	1.58	47.4	46.2	-1.2	-3.639
10-20	15	5.00	48.2	47.8	-0.4	-1.301
20-30	25	8.33	49.8	50.9	1.1	3.3197
30-40	35	11.67	52.3	55.7	3.4	10.251
40-50	45	15.00	55.5	62.0	6.5	19.492
51-55	53	17.67	58.7	68.2	9.5	28.548
55-60	57.5	19.17	60.7	72.2	11.4	34.292
60-65	62.5	20.83	63.2	76.9	13.7	41.223
65-70	67.5	22.50	65.8	82.0	16.2	48.731
70-75	72.5	24.17	68.6	87.6	18.9	56.817
75-80	77.5	25.83	71.7	93.5	21.8	65.481
80-85	82.5	27.50	74.9	99.8	24.9	74.722
85-90	87.5	29.17	78.4	106.6	28.2	84.541
90-95	92.5	30.83	82.0	113.7	31.6	94.937
95-100	97.5	32.50	85.9	121.2	35.3	105.91
100-105	102.5	34.17	89.9	129.1	39.2	117.46
105-110	107.5	35.83	94.2	137.4	43.2	129.59
110-115	112.5	37.50	98.7	146.1	47.4	142.3
115-120	117.5	39.17	103.3	155.2	51.9	155.58
120-125	122.5	40.83	108.2	164.7	56.5	169.44
125-130	127.5	42.50	113.3	174.6	61.3	183.88
130-135	132.5	44.17	118.6	184.9	66.3	198.9
135-140	137.5	45.83	124.0	195.5	71.5	214.49
140-145	142.5	47.50	129.7	206.6	76.9	230.67
145-150	147.5	49.17	135.6	218.1	82.5	247.42
150-155	152.5	50.83	141.7	230.0	88.2	264.74
155-160	157.5	52.50	148.0	242.2	94.2	282.65
160-165	162.5	54.17	154.5	254.9	100.4	301.13
165-170	167.5	55.83	161.2	267.9	106.7	320.19
170-175	172.5	57.50	168.1	281.4	113.3	339.83
175-180	177.5	59.17	175.2	295.2	120.0	360.04
180-185	182.5	60.83	182.5	309.4	126.9	380.84
185-200	187.5	62.50	190.0	324.1	134.1	402.21

Figure 10: Annual Incremental Hydro RECS (MWh) due to Transformer Replacement

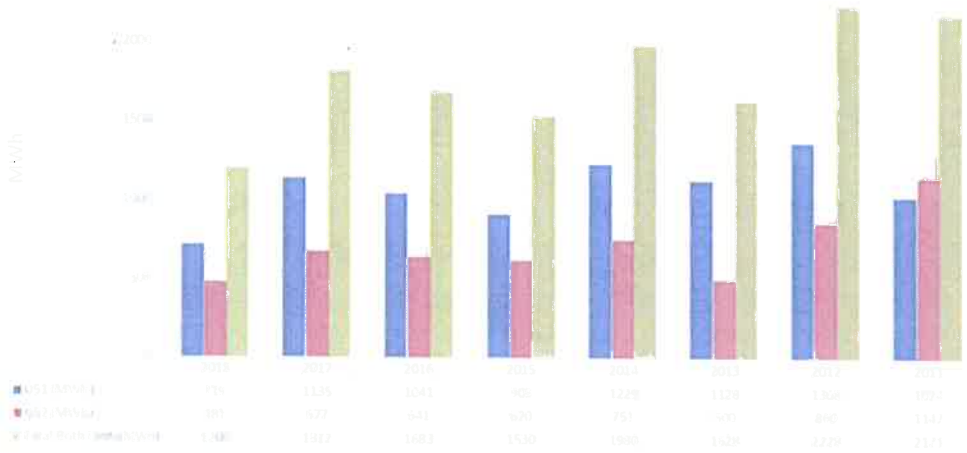


Figure 10 shows the annual incremental hydro results for years 2011-2018 for both Units 51 and 52. Beginning January 1, 2020, Tacoma Power plans to calculate actual annual incremental energy gain

(MWh) for the Mossyrock Transformer Replacement for Units 51 & 52 for Washington RPS Method One compliance using Equation 2 and the associated tables and figures described for future RPS compliance periods.

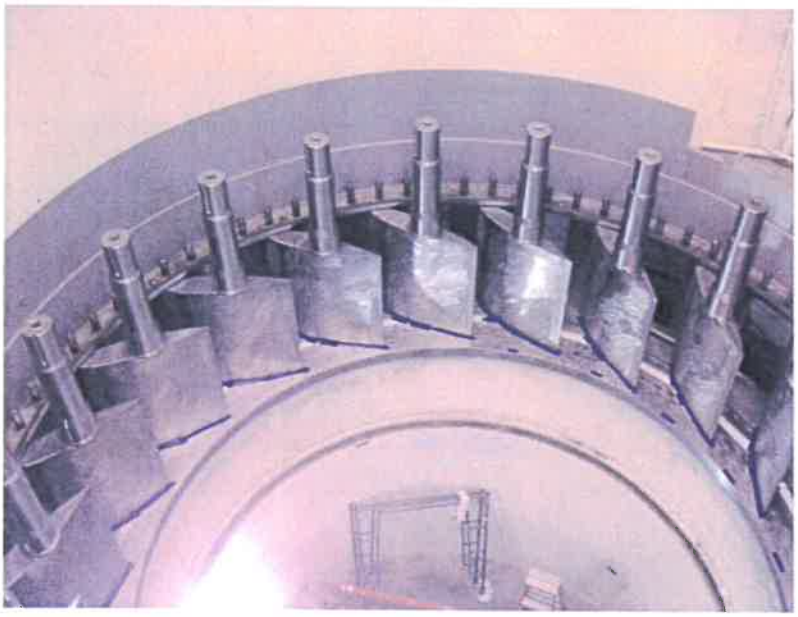
Engineering Review:

Mossyrock Rebuild Wicket Gate Calculations/Modeling

Mossyrock's Unit 51 and Unit 52 hydraulic turbines each have 20 identical wicket gates (or guide vanes) which control the flow of water through the turbines. The mechanism for the wicket gates forces them to move in unison, with matched angles and equal open areas. When opened, the area between the wicket gates forms a series of small openings around the turbine (see Figure 11). When closed, these gates form a relatively tight seal to minimize the leakage flow through the turbine so that the unit can be stopped; however, some leakage continues to squeeze past the wicket gates where they seal with each other (inter-gate leakage) and where they seal with the facing plates on the headcover and bottom ring (gate-end leakage).

Because Mossyrock's hydraulic turbines do not have upstream isolation valves, their wicket gates cannot be isolated after unit shutdown. Over the course of the year, the aforementioned leakage amounts to a significant amount of lost water (as high as 109 cfs before the rebuild, depending on lake elevation) and, thus, opportunity cost of lost generation.

Figure 11: Photo of Wicket Gate Seal Replacement



During the turbine rebuilds in 2010 and 2011, the facing plates on the headcover and bottom ring were modified to accept bronze gate-end seals. These end seals minimized the gaps between the wicket gates and facing plates, thus reducing the gate-end leakage (to 5-13 cfs, depending on lake elevation) and storing additional water to be used for generation throughout the year (see Figures 11 and 12).

Figure 12: Lower Gate-End Seal with Wicket Gate in Open Position

Reduced wicket gate leakage (for Units 51 and 52) was calculated for "pre-" (before-) and "post-" (after-) upgrade leakage rates. The amount of saved water that can subsequently be used for generation is highly variable and depends on the amount of time the wicket gates are closed (i.e., the generator is turned off) and the elevation of Riffe Lake (see Tables 12 and 13). Steps to determine the wicket gate incremental savings are as follows:

1. Determine Riffe Lake level ("Lake") and non-operating hours ("Hrs Not Operating") for Unit 51 & 52 from actual generation data.
2. Calculate the "Leak Rate" (cfs) at each lake level for the pre- and post-overhaul conditions using Equation 3, where Q_2 is the leak rate (cfs), z_{lake} is the lake level (ft), h_{ref} is the reference net head (ft) for the reference leak rate, and Q_{ref} is the reference leak rate (cfs) for the pre- or post-upgrade conditions.

$$Q2 = \sqrt{\frac{z_{lake} - 425\ ft}{h_{ref}}} * (Qref) \qquad \text{(Equation 3)}$$

Reference leak rates (Q_{ref} values) of 109 cfs at 345 ft head were used for the pre-overhaul condition and 13.15 cfs at 345 ft net head for the post-overhaul condition. The 13.15 cfs value was based on the average of 3 tests completed on one unit in the 2009–2010 timeframe (see Table 12).

Table 12: Mossyrock Leakage – Post-Rebuild Tests, 2009-2010

	20-May-09	10-Feb-10	10-Jun-10	
z_tail	425	425	425	
z_lake	765.7	719.75	770.45	
h_test	340.7	294.75	345.45	
Q_meas	12.91	10.90	14.68	
Adj to	351	351	351	
Ratio	1.02	1.09	1.01	AVG
Qadj	13.1	11.9	14.8	13.27
Adj to	345	345	345	
Ratio	1.01	1.08	1.00	AVG
Qadj	12.99	11.80	14.67	13.15

3. Calculate the estimated power loss ("Estimated PWR") (MW) associated with leakage in the pre- and post-upgrade conditions using Equation 4, where Q_2 is the leak rate (cfs), z_{lake} is the lake level (ft), and η_{TG} is the peak turbine-generator efficiency (94.58 %).

$$P = Q_2(z_{lake} - 430\ ft)\left(0.0846 * 10^{-3}\frac{MW}{\left[\frac{s^2 * W * ft^4}{kg * m^2}\right]}\right)\eta_{TG} \quad \text{(Equation 4)}$$

4. Calculate the "Estimated Energy" (MWh) associated with leakage in the pre- and post-upgrade conditions by multiplying the power ("Estimated PWR") (MW) by the "Hrs. Not Operating" and summing all for each unit.
5. Subtract the post-upgrade "Estimated Energy" totals from the pre-upgrade "Estimated Energy" totals for each unit to find the annual energy savings associated with the wicket-gate refurbishment.

Table 13: 2018 Incremental Hydro Generation due to Wicket Gate Seal Replacement

Mossyrock Leakage Value

Unit	Reference Points Leakage	Net Head	Timeline
	cfs	ft	
U51	109	345	Pre-Overhaul
U52	109	345	Pre-Overhaul
U51	13.15	345	Post-Overhaul
U52	13.15	345	Post-Overhaul

	Unit 51				Unit 52				Unit 51 Post Renovation			Unit 52 Post Renovation		
Lake	Hrs not Operating	Leak rate CFS	Estimate PWR (MW)	Estim Energy MW-Hr	Hrs not Operating	Leak rate CFS	Estimate PWR-MW	Estim Energy MW-Hr	Leak rate CFS	GE Leak Pwr -MW	JE Lost Energy MW-Hr	Leak rate CFS	GE Leak Pwr -MW	JE Lost Energy MW-Hr
680		73.1				73.1								
665	0	90.9	1.71	0	0	90.9	1.71	0	11.0	0.21	0	11.0	0.21	0
670	0	91.9	1.76	0	0	91.9	1.76	0	11.1	0.21	0	11.1	0.21	0
675	0	92.8	1.82	0	0	92.8	1.82	0	11.2	0.22	0	11.2	0.22	0
680	0	93.7	1.87	0	0	93.7	1.87	0	11.3	0.23	0	11.3	0.23	0
685	0	94.6	1.93	0	0	94.6	1.93	0	11.4	0.23	0	11.4	0.23	0
690	3	95.5	1.99	6	1	95.5	1.99	2	11.5	0.24	1	11.5	0.24	0
695	598	96.4	2.04	1223	475	96.4	2.04	971	11.6	0.25	148	11.6	0.25	117
700	55	97.3	2.10	116	32	97.3	2.10	67	11.7	0.25	14	11.7	0.25	8
705	275	98.2	2.16	594	355	98.2	2.16	767	11.8	0.26	72	11.8	0.26	93
710	781	99.1	2.22	1733	835	99.1	2.22	1853	12.0	0.27	209	12.0	0.27	224
715	214	99.9	2.28	488	276	99.9	2.28	629	12.1	0.27	59	12.1	0.27	76
720	306	100.8	2.34	716	326	100.8	2.34	762	12.2	0.28	86	12.2	0.28	92
725	650	101.6	2.40	1559	373	101.6	2.40	895	12.3	0.29	188	12.3	0.29	108
730	408	102.5	2.46	1004	347	102.5	2.46	854	12.4	0.30	121	12.4	0.30	103
735	382	103.3	2.52	963	339	103.3	2.52	855	12.5	0.30	116	12.5	0.30	103
740	741	104.2	2.58	1914	698	104.2	2.58	1803	12.6	0.31	231	12.6	0.31	218
745	344	105.0	2.65	910	391	105.0	2.65	1035	12.7	0.32	110	12.7	0.32	125
750	0	105.8	2.71	0	0	105.8	2.71	0	12.8	0.33	0	12.8	0.33	0
755	0	106.6	2.77	0	0	106.6	2.77	0	12.9	0.33	0	12.9	0.33	0
760	0	107.4	2.84	0	0	107.4	2.84	0	13.0	0.34	0	13.0	0.34	0
765	0	108.2	2.90	0	0	108.2	2.90	0	13.1	0.35	0	13.1	0.35	0
770	0	109.0	2.97	0	0	109.0	2.97	0	13.2	0.36	0	13.2	0.36	0
775	0	109.8	3.03	0	0	109.8	3.03	0	13.2	0.37	0	13.2	0.37	0
780	0	110.6	3.10	0	0	110.6	3.10	0	13.3	0.37	0	13.3	0.37	0
Total	4757			11228	4448			10493			1355			1266

Estimated Leakage Credit for I-937	Energy Savings
U51	9,872 MWh
U52	9,227 MWh
Total Leakage Savings	19,099 MWh

This increase in generation will be recalculated each compliance year. Mossyrock's lake levels and hourly generation data are provided annually by Tacoma Power's Production Engineering group. Beginning January 1, 2020, Tacoma Power plans to calculate actual annual incremental energy gain (MWh) for the Mossyrock Wicket Gate Sealing Replacement using Equations 3 and 4 and associated tables and figures for Units 51 and 52 for future RPS Method One compliance.

Summary

Based on updated calculations/modeling Tacoma Power proposes to report Incremental Hydro savings for the rebuild of Units 51 and 52 at our Mossyrock project, including the turbine-generators, transformers, and wicket gate sealing systems completed in 2011, in accordance with WAC 194-37-130 (3) (c) (ii) Method One – actual incremental generation.

We are planning to amend our 2019 Renewable Compliance report originally submitted on May 31, 2019, to reflect revised calculations and modelling for the Mossyrock rebuild once actual 2019 Mossyrock generation data is available for the calculations (see Table 14). The 2019 Amendment will also re-calculate the appropriate Apprenticeship credit per WAC 194-37-136 (1) for the rebuild project.

Pending approval of this Advisory Opinion, we are targeting RPS 2019 Amendment by May 1, 2020 and 2020 RPS reporting by June 1, 2020.

Table 14: Estimated 2019 Mossyrock Rebuild Amendment based on 2018 Generation Data

Rebuild Action	2019 Reported Generation (MWh)	Est 2019 Amended Generation (MWh)
Improved Turbine Efficiency	86,255	24,534
Improved Transformer Efficiency	270	1,200
Wicket Gate Sealing	12,500	19,099
Totals	99,025	44,833

Additional Vintage 2018/2019 eligible RECs currently owned by Tacoma Power will be reported/retired to cover the estimated 2019 RPS difference of 54,192 MWh for 2019 RPS compliance.

Application 2020-001

STATE OF WASHINGTON
DEPARTMENT OF COMMERCE
1011 Plum Street SE • PO Box 42525 • Olympia, Washington 98504-2525 • (360) 725-4000
www.commerce.wa.gov

April 29, 2020

To: Michael Furze, Assistant Director, Energy Division

From: Glenn Blackmon, Manager, Energy Policy Office

Digitally signed by: glenn.blackmon@commerce.wa.gov
DN: CN = glenn.blackmon@commerce.wa.gov
Date: 2020.04.29 15:14:13 -07'00'

RE: Decision Memo – Advisory Opinions 2020-001 (Mossyrock Dam)

Recommendation

Issue advisory opinions concluding that the incremental generation due to efficiency improvements at the Mossyrock hydroelectric project owned by Tacoma Power, as calculated using the method submitted with the utility's application, qualifies as an eligible renewable resource for purposes of the Energy Independence Act, Chapter 19.285 RCW.

Background

The Energy Independence Act ("EIA," also known as I-937) requires that qualifying electric utilities use renewable resources to meet a specified portion of customers' energy requirements and establishes eligibility standards for renewable resources used to meet this requirement.

The EIA defines hydropower as a renewable resource, but it limits the eligibility of this resource to the incremental electricity produced as a result of efficiency improvements completed after March 31, 1999. The hydroelectric projects must be located in the Pacific Northwest, and the additional generation must not result in new water diversions or impoundments.[1] Eligibility is also limited by ownership: The project must either be owned by a qualifying utility or owned by the federal government and marketed by the Bonneville Power Administration.

RCW 19.285.045 allows utilities and project owners to obtain an advisory opinion from Commerce regarding the eligibility of resources to meet a target under RCW 19.285.040. In this case, the advisory opinion from Commerce provides a basis to identify in the Western Renewable Energy Generation Information System the portion of each project's output that is eligible under the Washington renewable portfolio standard.

Procedural History

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[1] RCW 19.285.030(12)(b).

Tacoma Power, a qualifying utility under the EIA, submitted an advisory opinion application for the Mossyrock project on Jan. 30, 2020, and completed payment of the advisory opinion fee on Feb. 20, 2020. The application included engineering analysis, stamped by a registered professional engineer, documenting data and methodology supporting Tacoma's request.

Commerce posted the application on its website and provided an opportunity for public comment, as required by RCW 19.285.045. It received no comments. Tacoma Power provided supplement information at the request of Commerce on April 7, 2020.

Analysis – Eligibility of the Incremental Generation

The engineering analysis describes the improvements made that resulted in increased generation. Tacoma Power completed comprehensive upgrades of the two units in the Mossyrock project in 2010 and 2011. The upgrades included generators and turbines, transformers, and wicket gates. As discussed below, the efficiency improvements meet each of the elements of the eligibility requirements in RCW 19.285.030(12)(b):

- *The incremental generation must result from efficiency improvements.* The turbine and generator replacements, transformer replacements, and wicket gate end seal replacements result in greater hydroelectric output for any given quantity of water passing directly through the turbines.
- *The efficiency improvements must be completed after March 31, 1999.* Tacoma Power's application and engineering analysis confirm that the utility completed the upgrades after the statutory date.
- *A qualifying utility must own the hydroelectric generation project.* Tacoma Power is a qualifying utility and owns the Mossyrock project.
- *The hydroelectric generation projects must be located in the Pacific Northwest.* The Mossyrock project is located on the Cowlitz River in Lewis County, Washington.
- *The additional generation must not result in new water diversions or impoundments.* Tacoma Power has made no changes to the amount of water available to or impounded by the project, so the additional generation did not result in new water diversions or impoundments.

Analysis – Amount of Incremental Generation

Tacoma Power has described in its engineering analysis the approach used to determine the amount of electricity generated with and without the efficiency upgrades. The analysis concludes that over the period from 2011 to 2018, the upgrades allowed the project to generate and average of 49,668 MWh per year of additional generation. The additional generation is 2.46% of total generation on average.

Tacoma Power will calculate incremental generation each year based on actual stream flows and using the models described in its engineering analysis. The actual generation amounts and percentages will vary from the averages described here.

Conclusion

Incremental generation from the Mossyrock project is an eligible renewable resource under the Energy Independence Act, as long as the actual amount of incremental generation is determined each year using the method submitted with the utility's application.