California Air Resources Board

Greenhouse Gas Quantification Methodology for the Department of Water Resources State Water Project Turbines Greenhouse Gas Reduction Fund Fiscal Year 2013-14/2014-15

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A. Introduction

The California Air Resources Board (ARB) is responsible for providing the quantification methodologies to estimate greenhouse gas (GHG) emission reductions from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB staff developed the quantification methodologies outlined in this document to be used by the Department of Water Resources (DWR) for estimating GHG emission reductions from State Water Project (SWP) turbine runner replacement projects.

For fiscal year (FY) 2015-16 and future years, ARB will continue to develop or update quantification methodologies for GGRF funded programs, as needed.

Methodology Development

ARB and DWR staff followed a set of principles to guide the development of the quantification methodology for the turbine projects.

This methodology must:

- Apply at the project-level.
- Provide uniform methods that can be applied statewide.
- Use existing and proven tools or methodologies that are supported by empirical literature, where available.
- Estimate GHG emission reductions from the projected decrease in electricity purchases from the wholesale market.

GHG Emission Reductions

This methodology estimates the GHG emission reductions of the SWP turbine runner replacement projects based on the estimated decrease in wholesale market electricity purchases.

DWR will estimate the total GHG emission reductions from the program as a whole, as defined in the methodology, and report results as:

$$\frac{Total\ Program\ GHG\ Emission\ Reduction\ in\ Metric\ Tons\ (MT)\ of\ CO_2e}{GGRF\ Funds\ Requested\ (\$)}$$

DWR will also report the above metric for each hydroelectric turbine unit project. The following sections describe the calculations needed to estimate the GHG emission reductions for the projects under the FY 2013-14/2014-15 DWR SWP Turbines Program.

B. Quantification Methodology

This methodology estimates the GHG emission reductions of the water-energy efficiency improvements achieved by replacing two hydroelectric turbine runners in DWR SWP facilities. DWR replaced the hydroelectric turbine runners at two separate facilities of the Oroville-Thermalito complex located in the City of Oroville. One replacement is at the Edward Hyatt (Hyatt) Powerplant and the other replacement is at the Thermalito Pumping-Generating (Thermalito) Plant.

- The Hyatt plant has a total electricity generating capacity of 645 megawatts (MW) comprised of three conventional turbines each with a unit capacity of 117 MW and three pump-generator turbines each with a unit capacity of 97.75 megawatts.
- The Thermalito plant has a total electricity generating capacity of 115 MW comprised of one Kaplan turbine with unit capacity of 32.6 MW and three pump-generator turbines each with a unit capacity of 27.5 MW.

The turbine runner replacement projects result in an increase in the overall energy density and/or availability of the turbine units. The energy density (ED) (energy generation per unit volume) is reported as megawatt hours per acre-foot (MWh/ac-ft).

DWR will use the following four steps to estimate the GHG emission reductions for the projects, which accounts for the increase in hydroelectricity generation as a result of improved energy density and/or availability of the units, and subsequent decrease in wholesale electricity procurement.

Step 1: Calculate the Baseline Case by Unit/Project

The initial case for each hydroelectric turbine unit establishes a baseline of hydroelectricity production and turbine unit energy density. The hydroelectric energy production is determined using the turbine unit's historic energy production from monthly data collection by DWR. To establish a baseline energy density, the total historical plant hydroelectricity generation is compared against historical total water flow through the plant for hydroelectricity generation purposes. Ten years of historical data on SWP turbine operation provides a representative sample of fluctuations in California's hydrology and the associated energy, both generated and consumed.

The baseline hydroelectric energy generated by these turbine units and energy densities will be estimated using the following equations:

$$E_{unit\ baseline} = \frac{\sum_{i=1}^{120} E_{unit,i}}{120\ months} \quad \text{Eq. 1}$$

$$E_{plant\ baseline} = \frac{\sum_{i=1}^{120} \sum_{x=1}^{y} E_{i,x}}{120\ months} \quad \text{Eq. 2}$$

$$Q_{plant\ baseline} = \frac{\sum_{i=1}^{120} Q_{plant,i}}{120\ months} \quad \text{Eq. 3}$$

$$ED_{unit\ baseline} = \left(\frac{E_{plant\ baseline}}{Q_{plant\ baseline}}\right) \times \left(\frac{E_{unit\ baseline}}{E_{plant\ basline}}\right) = \left(\frac{E_{unit\ baseline}}{Q_{plant\ baseline}}\right) \quad \text{Eq. 4}$$

Where:

- $E_{unit\ baseline}$ = average monthly hydroelectricity generated by the turbine unit over 120 months (or 10 years) (MWh)
- $E_{unit,i}$ = monthly hydroelectricity generated by the turbine unit before the replacement for each given month, i (MWh)
- $E_{plant\ baseline}$ = average monthly hydroelectricity generated by the hydro power plant before the replacement (MWh)
- $E_{i,x}$ = monthly hydroelectricity generated by each turbine unit, x, for each given month, i, over 120 months (or 10 years) (MWh)
- y = number of units in the plant (i.e., Hyatt or Thermalito)
- $Q_{plant\ baseline}$ = average monthly water flow through the plant for hydroelectricity-generation purposes over 120 months (or 10 years) (ac-ft)
- $Q_{plant,i}$ = monthly water flow through the plant for hydroelectricity-generation purposes for each given month, i, over 120 months (or 10 years) (ac-ft)
- $ED_{unit\ baseline}$ = average energy density of the turbine unit before runner replacement over 120 months (or 10 years) (MWh/ac-ft)

Repeat Step 1 for each turbine project.

Step 2: Calculate the Project Case Conditions by Unit/Project

The project case represents the GHG emission reductions expected to occur after the turbine runners have been replaced. GHG emission reductions are anticipated to occur as the result of increased hydroelectricity generation due to improved energy density and/or availability of the turbine units. Increases in hydroelectricity generation will reduce DWR's need to utilize the incremental equivalent amount of electricity on the wholesale market.

Note: Estimates may not fully capture fluctuations in the quantity of water available to the power plant for hydroelectricity generation. These fluctuations depend on changes in hydrology (i.e., wet years vs. drought years) and other environmental and contractual factors (i.e., changes in water allotment due to contractual agreements).

GHG emission reductions from each turbine project (i.e., Hyatt and Thermalito) will be estimated using the following equations:

$$ED_{unit\ increase} = ED_{unit\ baseline} \times (1 + \eta) \quad \text{Eq. 5}$$

$$E_{new\ unit\ baseline} = Q_{plant\ baseline} \times ED_{unit\ increase} \quad \text{Eq. 6}$$

$$E_{unit\ increase} = E_{new\ unit\ baseline} - E_{unit\ baseline} \quad \text{Eq. 7}$$

$$GHG_{wholesale\ reductions} = 12\frac{months}{year} \times E_{unit\ increase} \times EF_{electricity} \quad \text{Eq. 8}$$

Where:

- $ED_{unit\ increase}$ = turbine unit energy density increase after replacement (MWh/ac-ft)
- η = manufacturer-specified turbine unit increase in efficiency (%)[1]
- $E_{new\ unit\ baseline}$ = estimated monthly turbine unit hydroelectricity generation after replacement (MWh)
- $E_{unit\ increase}$ = estimated monthly turbine unit hydroelectricity generation increase after replacement (MWh)
- $EF_{electricity}$ = California grid average emission factor (0.315 metric tons of carbon dioxide equivalent ($MTCO_2e$) per MWh)[2]

[1] This approach is for initial estimates only. After project completion, DWR-measured values will be used to update GHG emission reduction estimates for the turbine units.

[2] For the purposes of GGRF quantification methodologies, ARB developed a California grid electricity emission factor based on total in-state and imported electricity emissions ($MTCO_2e$) divided by total consumption in MWh. Emissions from ARB GHG inventory (2012), available online at: http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_sector_sum_2000-13_20150831.pdf. Consumption data from California Energy Commission (2012), available online at: http://energyalmanac.ca.gov/electricity/electricity_generation.html.

- GHG $_{\text{wholesale reductions}}$ = annual GHG emission reductions as a result of decreased procurement of electricity from the wholesale market ($MTCO_2e$) (multiplied by 12 in Eq. 8 to convert $E_{unit\ increase}$ from months to years)

Repeat Step 2 for each turbine project.

Step 3: Calculate the Lifetime Emission Reductions by Unit/Project

The estimated lifetime GHG emission reductions for each turbine project are calculated as follows:

$$GHG_{life} = GHG_{wholesale\ reductions}\ x\ Life \qquad \text{Eq. 9}$$

Where:

- GHG $_{\text{life}}$ = lifetime GHG emission reductions from each turbine unit project ($MTCO_2e$)
- Life = expected operating life of the turbine unit before additional improvements are needed to increase energy density and/or availability (i.e., 10 years)

Step 4: Calculate the Total Lifetime Emission Reductions for the Program

The estimated total lifetime GHG emission reductions (<u>sum of both turbine units</u>) per dollar of GGRF funds requested is reported as:

$$GHG_{\ Total\ life\ reductions\ per\ dollar\ GGRF} = \left(\frac{GHG_{\ Hyatt\ life} + GHG_{\ Thermalito\ life}}{GGRF\ Funds\ Requested}\right) \qquad \text{Eq. 10}$$

Where:

- GHG $_{\text{Total life reductions per dollar GGRF}}$ = total lifetime GHG emission reductions from both turbine runner replacements ($MTCO_2e$)
- GHG $_{\text{Hyatt life}}$ = lifetime GHG emission reductions from the Hyatt facility turbine runner replacement project ($MTCO_2e$)
- GHG $_{\text{Thermalito life}}$ = lifetime GHG emission reductions from the Thermalito facility turbine runner replacement project ($MTCO_2e$)
- GGRF Funds Requested = total dollar amount of GGRF funds requested ($)

C. Reporting and Documentation

The final step to complete this quantification methodology is to report the total GHG emission reductions from steps 3 and 4, and provide documentation for the turbine runner efficiency increases and calculations.

Reporting

DWR will report the total estimated GHG emission reductions from the program as a whole and for each hydroelectric turbine runner replacement project. For the DWR SWP Turbines Program, results must be reported as:

$$\frac{Total\ Program\ GHG\ Emission\ Reduction\ in\ MTCO_2e}{GGRF\ Funds\ Requested\ (\$)}$$

Documentation

DWR is required to capture and retain documentation that is complete and sufficient to allow the quantification calculations to be reviewed and replicated.

Documentation for each project (i.e., at Hyatt and Thermalito) and the DWR SWP Turbines Program as a whole will include:

- Contact information for the person who can answer project specific questions from staff reviewers on the quantification calculations;
- Project specifications for turbine runner replacements;
- Baseline energy estimations per unit, supported by DWR and California Energy Commission unit electricity production data;
- Baseline generation turbine unit energy densities derived from historical hydroelectricity generation and water flow data;
- Wholesale electricity purchases, supported by DWR wholesale electricity agreements;
- Manufacturer-specified turbine unit increase in efficiency;
- Post project wholesale electricity purchases supported by DWR wholesale electricity agreements; and
- Summary page with the following information, at a minimum:
    - GHG emission estimates for Baseline Case, Project Case, and Total Project Lifetime;
    - GGRF funds requested for the project; and
    - Total Lifetime Program GHG emission reductions per GGRF dollar requested.

ARB will continue to evaluate and update the GHG emission reduction quantification methodologies as necessary for future FY GGRF appropriations. Quantification methods are posted on ARB's auction proceeds webpage at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm

Questions on this document should be forwarded to GGRFProgram@arb.ca.gov.