



California ISO

Variable Operations and Maintenance Cost Review

Draft Final Proposal

August 12, 2020

Acronyms

APS – Arizona Public Service

CAISO – California Independent System Operator

CCGT – Combined cycle gas turbine

CT – Combustion turbine

DMM – CAISO Department of Market Monitoring

FERC – Federal Energy Regulatory Commission

MMA – Major maintenance adder

MRP – Middle River Power

MSG – Multi-stage generator

MW – Megawatt

MWh – Megawatt-hour

NYISO – New York Independent System Operator

NYSERDA - New York State Energy Research and Development Authority

O&M – Operations and maintenance

PGE – Portland General Electric

PSE – Puget Sound Energy

RDT – Resource data template

VM – Variable maintenance

VO – Variable operations

VOM adder – Variable operations and maintenance adder

USofA – FERC uniform system of accounts

WECC – Western Electricity Coordinating Council

ZLD – Zero liquid discharge

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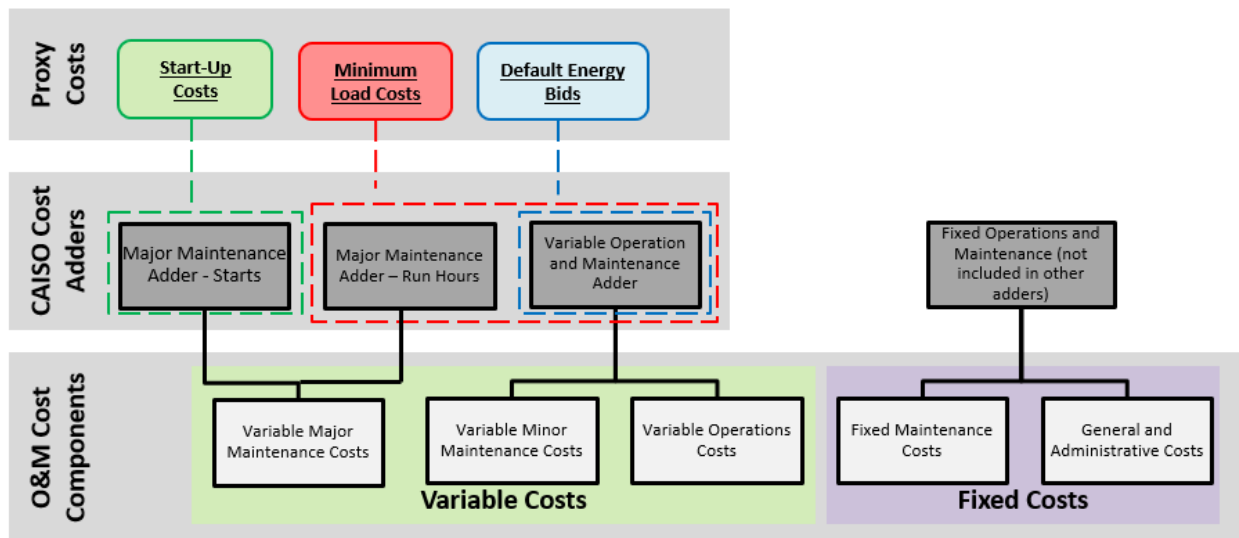
I. Executive Summary

This initiative proposes to change the structure of how operations and maintenance (O&M) costs are accounted for in the CAISO markets. It proposes principles for the categorization of O&M costs and updates how the “adders” that the CAISO markets use to reflect O&M costs are calculated.

Several issues that currently face the CAISO and market participants in the area of O&M costs prompted the need for this initiative. These issues originate from the lack of explicit, publically available principles for the categorization of O&M cost components. Without a shared understanding of these principles, negotiations between the CAISO and market participants can become overly complex and burdensome. In particular, CAISO and market participants must negotiate two adders that reflect O&M costs in the CAISO markets: the variable operations and maintenance (VOM) adder and the major maintenance adder (MMA). In addition to these recurring negotiations, the CAISO also revisits the default VOM adder values triennially. The triennial review has become challenging because there are no reference categories against which the CAISO can compare the existing default values. This initiative addresses these issues by proposing principles for use in the categorization of O&M cost components while also creating a cost framework that gives market participants more flexibility in bidding O&M costs into the CAISO markets and that provides more clarity and consistency in negotiating these adders.

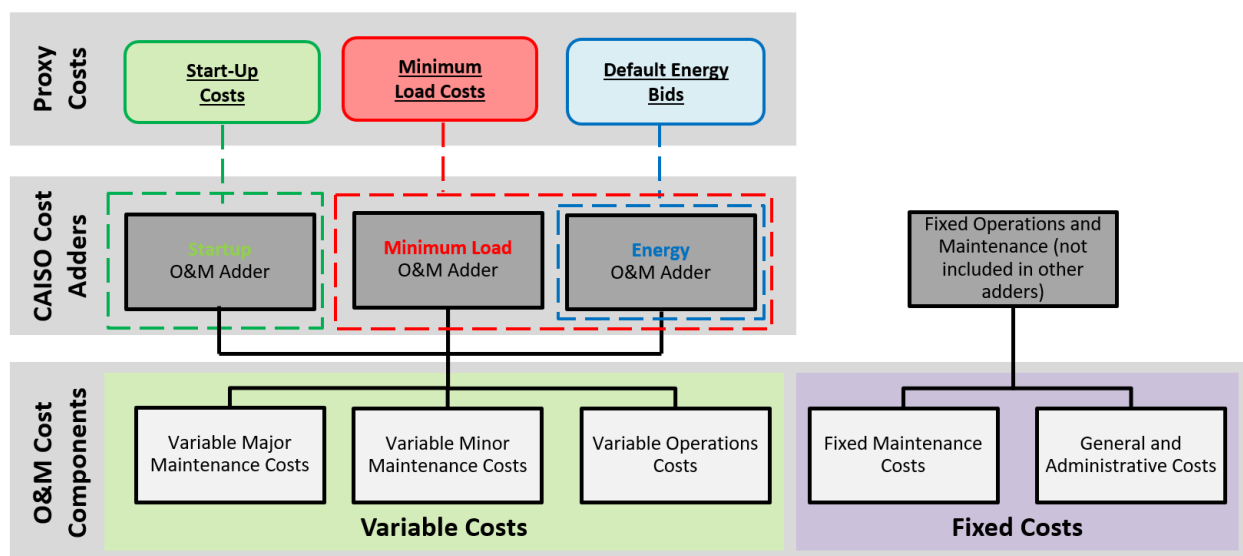
The current O&M cost framework is shown in Figure 1 below. The VOM and MMA adders that are currently in place allow market participants to include their O&M costs in their bids. The CAISO includes these adders in the resource’s “proxy costs” that mirror the three parts of market participants’ bids into the energy market: default energy bids, minimum load costs, and startup costs. The proxy costs are used in either the caps applied for costs market participants can bid in for minimum load costs and startup costs or the default energy bids for local market power mitigation. The VOM adder is included in default energy bids under the variable cost-based methodology and in minimum load costs under the Proxy Cost option. MMAs are included in minimum load costs and startup costs under the Proxy Cost option.

Figure 1 – Current Cost Recovery Framework in CAISO Markets



This proposal includes two components: 1) explicit proposal of the principles used to categorize O&M cost components to differentiate between fixed and variable O&M costs, 2) O&M Adders that replace the VOM adder and MMA; these adders can be included in any of the three Proxy Costs. The objective of each component of this proposal is to ensure market participants' bids can reflect these costs more accurately. The second component also proposes default values for the O&M Adders that can automatically apply to resources based on technology type so that market participants can avoid negotiating resource-specific values if the defaults are an adequate reflection of their costs. Market participants will still have the ability to negotiate O&M Adders with the CAISO, similar to how they can negotiate VOM adders and MMAs today. Figure 2 shows CAISO's proposal for the updated cost structure.

Figure 2 – Proposed Cost Recovery Framework in CAISO Markets



Section II will discuss more background and provide context as to why the CAISO is conducting this initiative. Section III will discuss the stakeholder comments received by the CAISO on the revised straw proposal and the changes that were made in reaction to those comments. Section IV will lay out the proposed principles, cost recovery framework, and default O&M Adder values; supporting discussion and details accompanying this section can be found in the Appendices. Section V discusses the role of the EIM Governing Body in relation to this initiative. Section VI will discuss the remaining timeline of stakeholder involvement for this initiative.

II. Background

The CAISO initially established the VOM adder values as part of a stakeholder initiative in 2012. To establish the adder values, the CAISO engaged an external consultant, Utilicast LLC., to analyze cost estimates from a variety of external sources and propose estimates on a generation technology-specific level. These are the cost estimates that the CAISO currently uses as default adders in the CAISO markets, *i.e.* generation technologies receive a pre-determined \$/MWh VOM value to be included in their default energy bids (DEBs) and minimum load costs. If market participants find that the default values are inadequate, they are able to negotiate VOM adder values with the CAISO.

Around this time, the CAISO introduced MMAs as part of the Commitment Cost Refinements 2012 stakeholder initiative. Potomac Economics, Ltd. was engaged to propose a framework for how major maintenance costs could be recovered in the CAISO markets. Major maintenance costs, such as costs incurred for major equipment overhauls, are incurred in large dollar-value increments at potentially irregular intervals. However, these costs are a direct result of the operation of a generating resource to produce electricity and are thus marginal costs recoverable in the CAISO energy markets. These costs were expected to be incurred based on the number of hours a generating resource is online and/or how many times a generating resource starts up in a given time period.

As described in the draft final proposal for the Commitment Cost Refinements 2012, CAISO and Potomac Economics, Ltd. planned on creating default MMAs. Stakeholders were generally supportive of the concept of default MMAs but were concerned about the data requirements and difficulty of calculating values that would apply to all resources within a technology group. Based on this feedback, the CAISO determined that market participants should instead negotiate resource-specific MMAs and, thus, the default MMA value were effectively set to zero.

In 2012, the CAISO committed to review the VOM adder values once every three years. The CAISO performed an internal review of the adder values in 2015 and did not change the adder values. In 2018, the CAISO engaged Nexant to conduct a more extensive review of the VOM adder values, resulting in a report being published in December 2018. The CAISO also held five working groups with stakeholders in July 2019 to discuss the Nexant report and O&M costs more broadly.

Through those working groups, the CAISO and stakeholders identified several issues with the current O&M cost framework. In particular, stakeholders noted that the CAISO did not have an explicit set of principles for what variable O&M costs are. For market participants, this leads to challenges in applying for MMAs and negotiated VOM adders. For the CAISO, this leads to difficulty in processing applications in a consistent and efficient manner and in quantifying the cost components in pursuit of updating the default VOM adder values. The current initiative was established to formally address the issues identified in these working groups.

III. Stakeholder comments and changes from revised straw proposal

Definitions comments and related changes

The CAISO appreciates the many helpful comments submitted by stakeholders related to the definitions proposed in the revised straw proposal. In response to these comments, the CAISO has made a number of minor modifications to the proposal. The largest changes that the CAISO has made in this draft final proposal relates to the treatment of replacements and a clarification on the treatment of unscheduled maintenance.

In the revised straw proposal, the CAISO proposed to use the FERC Uniform System of Accounts (USofA) definition of “retirement units” to determine whether a replacement would be considered a Variable Maintenance cost or not. Many stakeholders pointed out that this was inappropriate because the level of aggregation of “retirement units” varies across different organizations. Stakeholders proposed two ways to avoid reliance on the “retirement units” definition: 1) consider whether the replacement effects a substantial betterment (PGE), and 2) define the level of aggregation at the “major component” level

(DMM). Consequently, the CAISO has incorporated these two suggestions into this proposal as discussed further below.

Default O&M Adder values comments and related changes

The CAISO also appreciates the comments received on the proposed default adder values. In the revised straw proposal, the CAISO proposed default values for Variable Operations (VO) costs and default values for Variable Maintenance (VM) costs.¹

The comments regarding the default VO costs focused mainly on two items: 1) requesting that the CAISO consider creating default values for resources utilizing zero liquid discharge (ZLD) equipment and for wind resources and 2) expressing concerns that the default VO costs are understated:

- 1) Some stakeholders (MRP, APS) requested that the CAISO calculate a default value to reflect the VO cost of ZLD equipment. Based on the CAISO's understanding, this is not a technology used widely in the WECC region and thus should not be included in default values which apply to all resources within a technology type. Stakeholders (PSE) also suggested creating a default VO cost for wind resources, particularly to capture the costs of variable royalties paid to landowners on whose land the turbine is situated. The CAISO believes there is merit to this idea and determined that there is sufficient publicly available information to calculate a default value, as discussed further below.
- 2) Some stakeholders expressed concerns that the default VO costs are inadequate (*i.e.* too low) for their purposes. The CAISO believes that the default VO cost values developed by Nexant strike a reasonable balance between being generally useful while also being sufficiently conservative. As always, the negotiated option remains an option to market participants who find the default values insufficient.

The comments on the default VM costs were also instructive and helpful in improving the CAISO's calculations. While there wasn't a clear preference between Option 1 and Option 2, the comments were helpful in two ways: 1) proposing additional sources of O&M cost information and 2) considering how MMAs are utilized in the calculation of the default VM costs.

- 1) The CAISO thanks the stakeholders (PSE, DMM) that suggested alternative sources to use in the calculation of default VM costs. The CAISO doesn't use these sources as inputs into the proposed calculations because a) the technologies identified in the source document aren't the same as the CAISO's representative technologies, b) the sources are confidential or not publically available, and/or c) the CAISO's updated calculation approach, explained further below, does not accommodate the use of multiple sources for gas resources. However, these sources do serve as helpful points of reference for the calculation.
- 2) Several stakeholders (APS, PSE, DMM) discussed how MMAs are used in the calculation of the default VM costs. Stakeholders questioned why the MMAs are not used as the basis of the cost estimates. The CAISO notes that the MMAs are used as an input into the calculation but, rather

¹ In this draft final proposal, the CAISO uses different terms to refer to the default values compared to the revised straw proposal. For this section, the terms "default VO costs" and "default VM costs" are analogous to the terms "default VO adder" and "default VM adder", respectively, used in the revised straw proposal. This is explained in further detail in Section IV.

than using it as a primary input, the MMA values are used to cross-validate the external estimates, as discussed in more detail below. Also, the question was raised of whether MMAs are a reasonable cross-section of the resources of the CAISO markets. To address this question, the CAISO assessed factors such as Pmax and generation technology. Through this review, we noted that the resources with MMAs were substantially in line with the bulk of resources in the CAISO markets. Finally, in this draft final proposal the CAISO also updates how the MMA values used to cross-validate the external estimates are calculated; the calculation now uses the median value instead of an interpolated value derived from a linear regression.

IV. Proposal

This draft final proposal has two main parts: 1) proposing the principles to be used in the categorization of the O&M cost components for inclusion in the CAISO Tariff, and 2) proposing an updated O&M cost framework and the default values for the O&M Adders that comprise this cost framework.

Principles

The CAISO includes the proposed O&M cost categorization principles² in this section and provides interpretive guidance to the principles in Appendix A below³.

The O&M Adder is included in the default energy bid under the Variable Cost option and the Minimum Load Bid Cap and Startup Bid Cap under the Proxy Cost option. The O&M Adder reflects Variable Operations and Variable Maintenance costs that vary directly with the electricity output, run-hours, or start-up/shut-down of a Generating Facility. The CAISO proposes the following principles for categorization of the different O&M costs:

Variable Operations Costs:

Variable Operations costs are the costs of consumables and other costs that vary directly with the electrical production (i.e., the run-hours, electricity output, or the start-up/shut-down) of a Generating Facility, specifically excluding maintenance costs, greenhouse gas allowance costs, fuel costs, and grid management charges.

² Previous versions of this proposal used the term “definitions” to describe the language in this section. The CAISO believes that the term “principles” is more appropriate for this draft final proposal for two reasons: 1) the CAISO does not expect to include the language below in Appendix A to the CAISO Tariff, meaning that using the term “definitions” may be confusing in relation how this policy will be incorporated into the CAISO Tariff, and 2) the term “definitions” may imply that there is no ability to interpret the language in unforeseen circumstances or in situations requiring judgment and discretion. The CAISO does not intend for the principles to be completely flexible; rather, the use of the term “principles” acknowledges that real-life facts and circumstances may not fit neatly into fixed definitions. Hence, when confronted with an unanticipated circumstances or situations requiring discretion, the CAISO will consult the principles to aid in the categorization of O&M costs, instead of blindly applying definitions with no appreciation of the relevant facts and circumstances.

³ The CAISO may find that it needs to revise the principles as phrased below when it prepares the proposed tariff changes for inclusion in the amendment to the CAISO Tariff to implement this draft final proposal. For example, the CAISO may determine that the principles for the categorization of Variable Maintenance costs should be broken out into sub-components that separately address such costs related to run-hours, to electricity output, and to start-up/shut-down. In any event, the CAISO will post the draft tariff changes for stakeholder review and comment before it finalizes and files them with FERC.

Variable Maintenance Costs:

Variable Maintenance costs are the costs associated with the repair, overhaul, replacement, or inspection of a Generating Facility that adhere to the following conditions:

- 1) Such costs must vary with the electrical production (i.e. the run-hours, electricity output, or the start-up/shut-down) of the Generating Facility.*
- 2) Such costs should reflect future maintenance costs that are expected to be incurred within the service life of the major component of plant or equipment.*
- 3) Such costs should be consistent with good utility practice.*
- 4) Such costs should not effect a substantial betterment to the Generating Facility.*
- 5) If the item is a replacement, it cannot be a replacement of an existing major component of plant or equipment.*

Fixed Costs:

Fixed costs include fixed maintenance and general and administrative costs. Fixed maintenance costs are maintenance costs that do not vary with the electrical production (i.e. the run-hours, electricity output, or the start-up/shut-down) of the Generating Facility. General & administrative costs are non-maintenance costs incurred at a Generating Facility that do not vary with or relate to production (i.e. the run-hours, electricity output, or the start-up) of the Generating Facility.

O&M Cost Framework and Default O&M Adders

This section explains the proposed O&M cost framework and proposes default O&M Adder values by technology type.

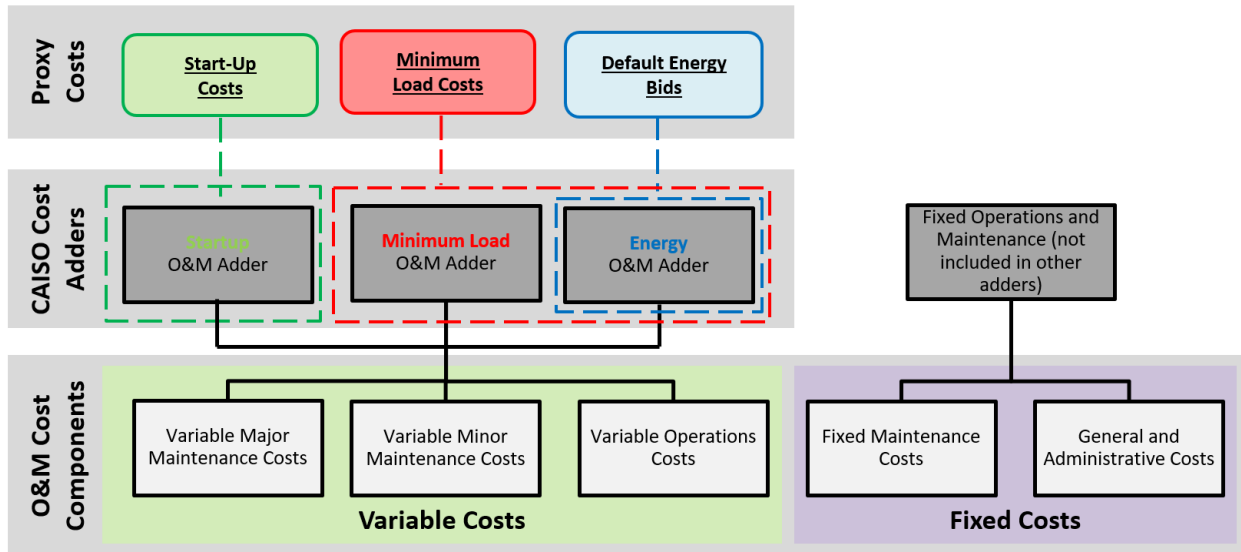
The proposed O&M cost framework allows *all* variable O&M cost components to be reflected in any of the three proxy costs⁴. This provides flexibility to market participants and gives them more ability to reflect their costs in the appropriate bid component. This is a departure from the current framework where only certain O&M cost components can be included in the bid components.

The default O&M Adders incorporate updated estimates for Variable Operations and Variable Maintenance costs developed over the past two years. There are three default O&M Adders: the Energy O&M Adder, the Minimum Load O&M Adder, and the Startup O&M Adder. The Minimum Load and Startup O&M Adders are analogous to the current major maintenance adders for minimum load and for startups and thus are included in the proxy minimum load costs and the proxy startup costs. The Energy O&M Adder is analogous to the current variable operations and maintenance adder and is thus included in the default energy bid and in proxy minimum load costs. Figure 3 shows this framework⁵ visually.

⁴ The term “proxy costs” refers to the CAISO’s estimate of a resource’s variable costs. They are expressed in the same format as the three-part bid (energy bids, minimum load bids, and startup bids). These proxy costs are used as the basis for the default energy bid, the minimum load bid cap, and the startup bid cap that are used in mitigation of energy bids and in limiting the minimum load and startup bids.

⁵ The cost framework may appear to be a change from the revised straw proposal but actually just represents a standardization of the language used. The definitions in the revised straw proposal allowed both Variable

Figure 3 – Proposed Recovery Framework in CAISO Markets



In this initiative, the CAISO proposes default values for each of the three adders that will apply to all generating resources within a technology type. The default values for the Minimum Load and Startup O&M Adders represent the CAISO’s estimate of Variable Maintenance costs and the default values for the Energy O&M Adders represent the CAISO’s estimates of Variable Operations costs. Depending on the technology type, some O&M Adders have \$0 default values. If the default values are found to be insufficient for specific resources, the framework continues to allow market participants to negotiate the O&M Adders. For example, if a market participant wishes to include Variable Maintenance costs in their Energy O&M adder, they can negotiate a custom Energy O&M adder with the CAISO⁶. See Table 1 for the default O&M Adder values.

Table 1 – Proposed default O&M Adder values

Technology Type	Energy O&M Adder (\$/MWh)	Minimum Load O&M Adder (\$/run-hour/MW ²)	Startup O&M Adder (\$/start/MW)
<i>Default values represents:</i>	<i>Variable Operations Costs</i>	<i>Variable Maintenance Costs</i>	<i>Variable Maintenance Costs</i>
Coal	2.69	-	-
Steam Turbines	0.33	-	-
CCGTs	0.59	1.74	-
[Frame] CTs	0.97	-	52.13

Operations costs and Variable Maintenance costs to be variable with respect to the run-hours, electricity output, or the start-up/shut-down, thus the representation presented above is a more accurate depiction of the proposal.

⁶ There are a few minor exceptions to this statement in regards to how resources with existing MMA or VOM adders can negotiate custom O&M Adder values. See Appendix D for more details.

⁷ The default Minimum Load and Startup O&M Adders are expressed in \$/run-hour/MW and \$/startup/MW units, respectively. To arrive at a resource-specific O&M Adder, the CAISO will multiply the proposed default value by the Pmax of the resource or configuration. This results in the resource-specific Minimum Load and Startup O&M Adders being expressed in \$/run-hour or \$/startup units, respectively.

Aeroderivative CTs	2.15	4.38	-
RICEs	1.10	-	-
Nuclear	1.08	-	-
Biomass Power Plant	1.65	-	-
Geothermal Power Plant	1.16	-	-
Land Fill Gas	1.21	-	-
Hydro	-	0.65	-
Solar	-	-	-
Wind	0.28	-	-
Storage/NGRs/PDRs/RDRRs	-	-	-

The O&M Adder values in Table 1 were developed in two ways: the Energy O&M Adder was developed by external consultant Nexant as an estimate of Variable Operations costs⁸ and the Minimum Load O&M Adder and the Startup O&M Adders were developed by the CAISO as an estimate of Variable Maintenance costs. The report issued by Nexant is included as Appendix F and the cost calculations developed by the CAISO are included as Appendix B. This delineation of estimates allowed for a clean separation of VM and VM costs resulting in what the CAISO believes is a conservative yet useful set of default values.

Key issues addressed in the development of the default O&M Adders

The main body of this paper will focus on a few key issues faced when developing these adders while much of the calculation detail and assumptions will be discussed in the Appendices. The key issues discussed here are the:

- *Cost estimation principles*
- *Technology grouping*
- *Methodology used to arrive at VM cost estimates*
- *Changes to the VM calculation methodology from the revised straw proposal*

Cost estimation principles

A key principle affecting the CAISO’s estimates is that the estimates need to be sufficiently conservative while also still attractive for use in lieu of negotiated O&M Adder values. Ensuring our estimates are conservative is important for a few reasons. First, these values are used in local market power mitigation to ensure that resources with the ability to exercise local market power cannot bid above their costs. Proxy cost estimates greater than resources’ costs introduce a potential inefficiency into the market if these proxy costs clear the market. Second, once the values are in place, only resources with costs higher than the defaults will approach the CAISO to negotiate their adders. If the default values are too high, the CAISO will have no visibility into whether resources’ actual costs exceed the proposed estimates. However, the concept of the default Minimum Load and Startup O&M Adders is being introduced to balance with the associated administrative burden of processing many resource-specific negotiations for both market participants and the CAISO. The CAISO believes the proposed default

⁸ The exception to this is the VO cost estimate for wind resources that were developed internally by the CAISO. See Appendix E for the detailed calculation.

values are a reasonable balance between being conservative while also useful for participants as default values.

The CAISO also applies several principles in selecting the external sources of O&M cost estimates. The CAISO has identified publicly available sources that are appropriate definition-wise, geographically appropriate (or could be converted across geography), temporally applicable (or could be converted across time), technologically appropriate, and credible. The CAISO also strives to use a calculation methodology that is responsive to the data constraints presented for each technology type. These principles help the CAISO ensure that the O&M cost estimates used in the default O&M Adder values are accurate and defensible.

Technology grouping

The proposed default VM values cover four technology types covering approximately 75% of resources with identifiable VM costs⁹. The CAISO strives to group technologies at a level that is sufficiently granular to capture cost differences between technologies while also being sufficiently aggregated to be widely applicable and not exclude technologies. In cases where a technology group was commonly represented by a particular technology type (e.g. 55% of Aeroderivative CTs in the CAISO/EIM footprint are GE LM6000s), those technologies are used as “representative technologies” and cost estimates for these particular technologies are used. For those technology groups that do not have default values, the CAISO either believes that the technology group does not have Variable Operation or Variable Maintenance costs (e.g. the Solar technology group) or insufficient data exist to estimate these costs that abide by our cost estimation principles (e.g. the Steam technology group).

Changes to the VM calculation methodology from the revised straw proposal

In this draft final proposal, the CAISO has changed a few aspects of the calculation presented in the revised straw proposal. The revised straw proposal offered two options to calculate the default VM costs and requested that stakeholder weigh in on their preferred option. Because the feedback did not favor one option over the other, the CAISO primarily uses “Option 1” as discussed in the revised straw proposal. This option is characterized by using a single external source per technology type and using no unit conversions that rely on CAISO-developed conversion factors. The exception to this is Hydro resources, which uses an approach similar to “Option 2” as discussed in the revised straw proposal.

The CAISO’s decision to use this blended approach of Option 1 and Option 2 is informed by stakeholder feedback and guided by the cost estimation principles discussed above. The blended approach is similar to the approach discussed by PGE in their comments and is responsive to the concerns expressed by DMM and other stakeholders. Using Option 1 for gas technologies represents a conservative approach to developing the cost estimates as it involves fewer assumptions and has the benefit of simplicity. The external sources for the gas technologies also have technology-specific (e.g. LM6000-specific) cost estimates and, thus, using a single source is preferred. Using Option 2 for hydro technologies is appropriate as detailed technology-specific cost estimates are not as widely available for hydro resources as they are for gas resources; thus a diversity of estimates better suits the hydro technology group. The hydro cost estimates involve only a few assumptions that the CAISO believes that the

⁹ For the purposes of this calculation, the CAISO ignores technology types which don’t have maintenance activities which can be specifically linked to their variable production (e.g. solar photovoltaic resources).

assumptions are adequately supported. The CAISO views the differences in approach as a strength in our methodology, rather an inconsistency or a flaw, because the differences are responsive to the unique challenges posed by estimating costs for gas versus hydro technologies.

Methodology used to arrive at VM cost estimates

The process the CAISO uses to calculate the VM cost estimates which are the basis of the default Minimum Load and Startup O&M Adders consists of five steps. While these steps are shown in greater detail in Appendix B, this section will discuss each step briefly.

- 1) Estimate variable maintenance costs using external sources
- 2) Determine which adder type (\$/run-hour, \$/start, or \$/MWh adder) is most appropriate for each technology type
- 3) Convert the variable maintenance costs to the appropriate adder type
- 4) Cross-validate the estimate from external sources against median major maintenance adder values to determine a default O&M Adder value
- 5) Using the default O&M Adder value, calculate a resource-specific O&M Adder

Step 1: Estimate variable maintenance costs using external sources

The CAISO uses external sources to estimate VM costs. As discussed above, the CAISO considers several criteria to ensure that the external sources used are appropriate. Ultimately, the CAISO uses four sources based on those criteria: NYISO (2010), NYISO (2016), EPA (2018), and EIA (2020). The CAISO then gathers the cost data from the source documentation and converts the costs estimates to factor in differences in costs arising from temporal and geographic differences.

Step 2: Determine which adder type (\$/run-hour, \$/start, or \$/MWh adder) is most appropriate for each technology type

Once the external estimates have been converted to consistent units, the CAISO needs to determine which adder type is most appropriate as a default value for each technology type. Because the CAISO proposes to apply the default values to all resources within a technology type, the CAISO must determine a default adder type for each technology. To do so, the CAISO considers which factor typically most influences maintenance actions (*i.e.* whether starts, run-hours, or MWh are the primary drivers of maintenance costs) and which type of MMA is currently most prevalent for that technology type. Based on this, the CAISO proposes that the default adder for the Aeroderivative CT, CCGT, and Hydro technology types are best represented by a \$/run-hour default value, while frame CTs are best represented by a \$/start default value.

Step 3: Convert the variable maintenance costs to the appropriate adder type

The external cost estimates are not presented in the adder type format that is proposed in Step 2. This conversion is a simple mathematical exercise and uses unit conversion factors found in the source documentation (gas resources) or derived from CAISO and EIM operating data (hydro resources).

Step 4: Cross-validate the estimate from external sources against median major maintenance adder values to determine a default O&M Adder value

The CAISO proposes to limit the proposed default VM cost values to the median of currently approved MMA values. This is in accordance with the CAISO’s principle that the estimates should be sufficiently conservative while also still attractive for use in lieu of negotiated O&M Adder values. For technology types in which the external sources exceed the median MMA values, the CAISO will use the median of the MMA values. The median value was calculated for only those technology types with a sufficient number of MMAs¹⁰.

The CAISO presents the proposed default O&M Adders in Table 2. Table 2 also shows the median MMA values for those technologies where the external estimate exceed the median MMA values. For the technologies where the median value negotiated MMAs exceed the external estimates, the CAISO is not disclosing these values for confidentiality purposes. The far right column shows the proposed default O&M Adder calculated as follows for each technology type:

$$\text{Default O\&M Adder} = \min(\text{External Estimate VM Costs}, \text{Median MMA Value})$$

Table 2 – Proposed default O&M Adder values

Technology Type	External Estimate VM Costs	Median MMA Values	Default O&M Adders	Units
CCGTs	1.74	-	1.74	\$/run-hour per MW
[Frame] CTs	52.13	-	52.13	\$/start per MW
Aeroderivative CTs	4.38	-	4.38	\$/run-hour per MW
Hydro	1.12	0.65	0.65	\$/run-hour per MW

Step 5 – Using the default O&M Adder value, calculate a resource-specific O&M Adder

The CAISO proposes to use of the maximum generating capacity of the resource (*i.e.*, its Pmax) to scale default O&M Adder to be a resource-specific O&M Adder. If the resource is a multi-stage generator (MSG), the CAISO proposes to calculate the resource-specific O&M Adder using the Pmax of each configuration to reflect the incremental costs of wear-and-tear of operating of each configuration. Note that this logic only applies to the Minimum Load and Startup O&M Adders; the Energy O&M Adder is not scaled by the Pmax of the resource or configuration. The resulting unit-specific adder calculation is proposed as follows:

$$\text{Resource-specific O\&M Adder} = \text{Default O\&M Adder} * \text{Resource's Pmax}$$

Or if the resource is a multi-stage generator (MSG):

$$\text{Configuration-specific O\&M Adder} = \text{Default O\&M Adder} * \text{Configuration's Pmax}$$

The resource-specific or configuration-specific O&M Adder will then be used by the CAISO systems to calculate the minimum load bid cap or the startup bid cap.

¹⁰ The CAISO concludes that a sufficient number of MMAs was that the technology type has to have at least 20 resources with negotiated MMAs based on actual costs, rather than PPAs or LTSAs. For multi-stage generators, the CAISO uses only the first configuration or, in the case of CCGTs, the 1X1 configuration for the purposes of this calculation.

V. EIM Decisional Classification

This initiative proposes to modify rules for establishing variable operations and maintenance cost values in the CAISO’s estimates of generating resources’ costs used for market power mitigation.

An initiative proposing to change rules of the real-time market falls within the primary authority of the EIM Governing Body either if the proposed new rule is EIM-specific in the sense that it applies uniquely or differently in the balancing authority areas of EIM Entities, as opposed to a generally applicable rule, or for proposed market rules that are generally applicable, if “an issue that is specific to the EIM balancing authority areas is the primary driver for the proposed change.”

At this stage of the initiative, it does not appear it would satisfy the first test, because any proposed rule changes would be generally applicable to the entire CAISO market footprint, both the real-time and day-ahead market, and thus are not EIM-specific. Moreover, the primary driver for addressing these topics is not specific to the EIM balancing authority areas. Rather, the initiative stems from issues raised in an internally-driven review of these costs. Accordingly, this initiative would fall entirely within the advisory role of the EIM Governing Body.

VI. Stakeholder Timeline

The schedule for stakeholder engagement is detailed below in Table 3. The CAISO will discuss this draft final proposal paper with stakeholders during a call on August 19 at 09:00AM PT. Stakeholders can submit written comments regarding this draft final proposal paper by September 2, 2020 through the CAISO’s new commenting tool.

Please note that the dates below are tentative until the CAISO publishes a market notice formally confirming them.

Table 3 – Stakeholder timeline

Date	Milestones
December 19, 2019	Post Straw Proposal
January 6, 2019	Hold stakeholder call on Straw Proposal
January 21, 2019	Stakeholder written comments due on Straw Proposal
May 4, 2020	Post Revised Straw Proposal
May 11, 2020	Hold stakeholder call on Revised Straw Proposal
May 26, 2020	Stakeholder written comments due on Revised Straw Proposal
August 12, 2020	Post Draft Final Proposal
August 19, 2020	Hold stakeholder call on Draft Final Proposal
September 2, 2020	Stakeholder comments due on Draft Final Proposal
Aug. - Sept. 2020	Tariff & BRS Development

November 4, 2020	EIM Governing Body
November 18-19, 2020	Board of Governors

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VIII. Appendices

A) Principles – Interpretive Guidance

This section will provide interpretive guidance on Variable Operations and Variable Maintenance costs and will offer specific guidance on labor costs that applies to both cost categories.

Variable Operations Costs

Variable Operations costs are the costs of consumables and other costs that vary directly with the electrical production (i.e., the run-hours, electricity output, or the start-up/shut-down) of a Generating Facility, specifically excluding maintenance costs, greenhouse gas allowance costs, fuel costs, and grid management charges.

As explained in the principle above, Variable Operations (VO) costs arise directly as a result of operating the Generating Facility but don't include maintenance, greenhouse gas allowance, or fuel costs. Examples of VO costs include consumable materials, production-based fees such as royalties paid to landowners, and costs associated with the energy needed to cool critical components. These costs also exclude existing costs in reference levels such as the grid management charge and opportunity cost adders.

The CAISO will outline a few specific examples here to further define VO costs:

- Consumables specifically include raw and demineralized water, boiler chemicals, cooling tower chemicals, and ammonia.
- Production-based fees such as royalties paid to landowners are VO costs. The CAISO would expect to see these fees spelled out explicitly in a contract such as a power purchase agreement (PPA) or in enacted regulation (e.g. fees due to FERC or other regulatory authorities/groups).
- VO costs also include cost of consumables and other costs related to pre-start, start, shutdown activities, and return to pre-start stand-by conditions as long as the costs can be clearly demonstrated as variable.

Variable Maintenance Costs

Variable Maintenance costs include costs that are incurred when repairing, overhauling, and inspecting the Generating Facility. Costs of replacing equipment may also be included under specific circumstances such as replacing a non-major component due to the wear-and-tear of operating the component. Examples of Variable Maintenance activities include hot gas path inspections, combustion inspections, and major overhauls inspections. Routine maintenance including standby maintenance performed during off-peak periods may also be Variable Maintenance as long as the maintenance activities vary with the electrical production of the unit.

The CAISO stresses that these costs are those that vary with the electrical production of the unit; they arise due to the wear-and-tear on the Generating Facility because it is engaged in the production of electricity. Further, they are costs incurred to maintain the Generating Facility, not to substantially alter it beyond its original characteristics.

This section provides interpretative guidance on the components of the principles for the categorization of Variable Maintenance costs. The CAISO expects to include this guidance in the BPMs upon

implementation of this initiative. This guidance is intended to be useful during the negotiation of custom O&M Adders and may also inform the CAISO's estimate of the default O&M adder values. As a reminder, the principles for the categorization of Variable Maintenance costs are included below; any underlined terms are interpreted further below.

Variable Maintenance costs are the costs associated with the repair, overhaul, replacement, or inspection of a Generating Facility that adhere to the following conditions:

- 1) *Such costs must vary with the electrical production (i.e. the run-hours, electricity output, or the start-up/shut-down) of the Generating Facility.*
- 2) *Such costs should reflect future maintenance costs that are expected to be incurred within the service life of the major component of plant or equipment.*
- 3) *Such costs should be consistent with good utility practice.*
- 4) *Such costs should not effect a substantial betterment to the Generating Facility.*
- 5) *If the item is a replacement, it cannot be a replacement of an existing major component of plant or equipment.*

Costs must vary with the electrical production

This is the core principle of variable costs and is often the deciding factor in determining whether a cost is Variable Maintenance or not. For the purposes of O&M costs, the CAISO analyses electrical production in three ways: 1) the electricity output of the resource measured in terms of MWh, 2) the length of time that the unit is committed and producing electricity at or above its minimum load measured in terms of run-hours, and 3) the frequency of starting up the resource or, if the resource is a multi-stage generator, transitioning to higher configurations. This means that, for a maintenance cost to be considered variable, it must vary with respect to one of these three measures. Costs that are incurred regardless of these measures are by definition fixed. Fixed costs are not recoverable via the CAISO's spot energy markets. The CAISO recognizes that there are sometimes situations where the maintenance initially appears to be calendar based, but is actually production based; this is discussed in more detail below.

Start-up/shut-down

VM costs also include cost of repair, overhaul, replacement, or inspection related to pre-start, start, shutdown activities, and return to pre-start stand-by conditions as long as the costs can be clearly demonstrated as variable.

Generating Facility

This term is defined in the Tariff as *"An Interconnection Customer's Generating Unit(s) used for the production and/or storage for later injection of electricity identified in the Interconnection Request, but shall not include the Interconnection Customer's Interconnection Facilities."* For the purposes of negotiating custom O&M Adders, this will broadly include the major components of the Generating Unit and any plant or equipment in the Generating Facility whose maintenance activities can be shown to vary with electrical production.

Future maintenance costs

This term means that the costs must be reasonably expected to be incurred at some point in the future. Historical, *i.e.* sunk, costs cannot be included in the O&M Adder. However, historical costs are often useful in estimating future costs. In this case, historical costs can be used as a starting point in estimating future maintenance costs as long as the costs are reasonably expected to be incurred in the future. For example, resources may discover the need for unplanned maintenance during an inspection. If the maintenance has already been performed, the cost to repair these specific issues cannot be included in the O&M Adder. However, these unplanned maintenance activities may be an indication that the resource can expect to incur more unplanned maintenance costs in the future for similar reasons. If so, and the market participant can demonstrate that the remaining conditions of the principles are met, the estimate of the costs for unplanned maintenance to be performed in the future would be considered Variable Maintenance costs.

Service life (and maintenance intervals)

Service Life understanding:

This term is consistent with the term used in the FERC Uniform System of Accounts (USoA) and is assessed at the major component level (see further discussion below). Service life means the period between the date that property is placed in service and the expected date of its replacement or retirement. Because the major component is an integral part of the Generating Facility, the service life of a major component cannot exceed the service life of the Generating Facility as a whole.

Major components' service life may be defined in terms of production or in terms of calendar time. In the former case, service life can be presented in terms of run-hours, start-ups/shut-downs, MWh production, a permutation of these factors (e.g. factored hours), or a blend of these factors. Service life may also be defined to terms of calendar time.

Through previous negotiations of MMAs, the CAISO has determined that certain maintenance activities are unlikely to be performed within the service life of the Generating Facility and thus has disallowed those costs from being considered as being included in the MMA. The CAISO expects to continue this policy after the components of this initiative are implemented. For example, a resource may apply for a cost associated with a maintenance activity that would occur very far into the future (e.g. over 100 years). In such cases, the CAISO has determined that such a maintenance activity is unlikely to occur and thus the associated cost of wear-and-tear will never be incurred. Conversely, in cases where there is a reasonable expectation that the maintenance activity will occur based on the operating profile of the resource, the CAISO has allowed those costs to be included in the MMA. During the negotiation process, market participants may be able to provide persuasive documentation of the Generating Facility's service life such as permits, warranties, etc. Based on the review of this documentation and the facts and circumstances surrounding the resource and its maintenance activities, the CAISO will determine whether there is a reasonable expectation that the maintenance activity will be performed.

Maintenance Intervals understanding:

While not explicitly included in the principle above, the CAISO will refer to maintenance intervals as they are related conceptually to service life. In practice, the maintenance interval is usually defined in

terms of either production or calendar time. If the maintenance interval is in terms of production (e.g. perform a hot gas path inspection once every 25,000 hours), the costs vary with production and, thus, will be considered Variable Maintenance, subject to the other conditions of the principles.

If the maintenance interval is in terms of calendar time (e.g. perform a hot gas path inspection every 10 years), the situation is more complicated. If the maintenance will be performed regardless of production at the end of the maintenance interval, the costs are not Variable Maintenance costs. However, as DMM points out in their comments to the revised straw proposal, there are sometimes situations where the maintenance initially appears to be calendar based, but is actually production based. For example, a 10-year maintenance interval may be initially defined in terms of calendar time. However, implicit in the estimate of the 10 years is an expectation of how many hours per year the major component will be used (e.g. 2,500 hours per year for 10 years) because of the wear-and-tear on the unit. In this case, the maintenance interval in terms of production (in this example, 25,000 hours) may actually be more appropriate.

Major component

The CAISO uses the term “major component” in two situations: 1) in considering the unit of account for assessing service life, and 2) in considering whether a replacement is a Variable Maintenance costs or not. The major component is the “unit of account” on which we consider these two issues. The unit of account is the level at which the CAISO proposes to group plant and equipment. For example, for frame combustion turbines, we define the major components, and thus the units of account, to be 1) the gas turbine and 2) the generator. The CAISO understands that the individual facts and circumstances of plants vary and thus these major component classifications are only a starting point. The CAISO considered alternatives to this level of aggregation that were less granular (e.g. the entire Generating Facility) or more granular (the compressor, the combustion system, etc.). However, the CAISO believes that the major components represent a reasonable balance between levels of aggregation and are representative of the industry standard.

Generally, during O&M Adder negotiations, the CAISO will assess the service life at the major component level unless a valid reason can be supplied for such an alternative treatment.

During O&M negotiations, the CAISO will not consider replacement of *major components* to be Variable Maintenance. However, the CAISO will consider replacement of *the constituent parts of the major component* to be Variable Maintenance, provided that they meet the remaining conditions of the principles outlined above. For example, if the entire turbine needs to be replaced, the costs associated with this would not be consider Variable Maintenance costs. The rationale for this is that this replacement is not serving to return the major component to a state similar to its original condition (*i.e.* maintaining it) but rather replacing it entirely. A counterexample to this is a replacement of a compressor; in this case, the replacement of the compressor is a constituent part of the major component and thus would be a Variable Maintenance cost (assuming the other conditions in the principles are met). The replacement of the constituent part (*i.e.* the compressor) is performed in order to bring the major component (*i.e.* the turbine) back to its original condition; in other words, the replacement was performed to maintain the turbine. The unit of account distinction is crucial here because the CAISO needs to be able to distinguish the treatment of the turbine from the treatment of the turbine blade. Table 4 shows the list of typical major components by technology:

Table 4 – Typical major components by technology

<ul style="list-style-type: none"> - <u>Frame and Aero-derivative CTs</u> <ul style="list-style-type: none"> • Gas turbine • Generator 	<ul style="list-style-type: none"> - <u>Combined Cycle Gas Turbines</u> <ul style="list-style-type: none"> • Gas turbine • Steam turbine • Generator • Heat recovery steam generator
<ul style="list-style-type: none"> - <u>Biomass</u> <ul style="list-style-type: none"> • Turbine • Generator • Feedwater system/condensate • Boiler 	<ul style="list-style-type: none"> - <u>Geothermal</u> <ul style="list-style-type: none"> • Steam turbine • Generator • Feedwater system/condensate
<ul style="list-style-type: none"> - <u>Coal and Steam Turbines</u> <ul style="list-style-type: none"> • Steam turbine • Generator • Feedwater system/condensate • Boiler • Pulverizer 	<ul style="list-style-type: none"> - <u>Hydro</u> <ul style="list-style-type: none"> • Turbine • Generator • Penstock/intake structure • Penstock control gates • Trash racks • Power house • Reservoir/dams
<ul style="list-style-type: none"> - <u>Nuclear</u> <ul style="list-style-type: none"> • Steam turbine • Generator • Steam generators • Feedwater system • Reactor vessel • Reactor cooling pumps 	<ul style="list-style-type: none"> - <u>Internal Combustion Engines</u> <ul style="list-style-type: none"> • Engine • Generator
<p>Other technology types: No defined major components, these will be assessed during individual negotiations</p>	

Good utility practice

A summary of the FERC definition of Good Utility Practice is:

- Any practices, methods, or acts engaged in or approved by a significant portion of the electric utility industry, or
- Any practices, methods, or acts which, in the exercise of reasonable judgement, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practice, reliability, safety, and expedition.

Substantial betterment

A substantial betterment is an action “the primary aim of which is to make the property affected more useful, more efficient, of greater durability, or of greater capacity”. Substantial betterments improve a resource, not maintain it, and thus are not Variable Maintenance costs.

FERC also notes: “When a minor item of depreciable property is replaced independently of the retirement unit of which it is a part, the cost of replacement shall be charged to the maintenance account appropriate for the item, except that if the replacement effects a substantial betterment ..., the excess cost of the replacement over the estimated cost at current prices of replacing without betterment shall be charged to the appropriate electric plant account.” Applying this logic to the CAISO’s principles, this means that the some of the costs of a maintenance action that results in a substantial betterment may be considered Variable Maintenance costs and some may not. The “excess costs of the replacement over the estimated cost at current prices of replacing without betterment” will not be Variable Maintenance costs while the remaining costs will be.

Table 5 maps the enumerated criteria in the substantial betterment definition to the corresponding Master File/RDT fields. This table isn’t intended to be exhaustive but rather illustrative.

Table 5 – Mapping of substantial betterment criteria to Master File/RDT fields

Criteria	Master File field	A substantial betterment if the action...
More useful	FUEL_TYPE	Allows the resource to burn multiple types of fuel
	CONFIGURATION	Allows the resource to operate as a multi-stage generator, e.g. by creating steam augmentation or duct-firing capability
More efficient	HEAT_RATE	Decreases the average heat rate of the resource/segment beyond its original operating characteristics
	AVERAGE_COST	Decreases the average cost of the non-gas resource/segment beyond its original operating characteristics
Greater durability	N/A	Increases the service life of the major component beyond its original design
Greater capacity	MAX_GEN	Action increases the Pmax of the resource beyond its original design

While this seems simple, the practical application of this is not as clear as it seems. Some activities serve both to bring the resource back to its original condition but also to improve it. In this case, some of the costs can be Variable Maintenance costs while some are not. The CAISO shows multiple scenarios below which may help in considering how to treat substantial betterments to the resource and proposes some potential cost allocation methodologies. These scenarios presuppose that the other conditions in the Variable Maintenance principles are also met.

Scenario 1 – Steam turbine

Service Life: Partially complete (20,000 hours left)

Replacement: Sub-component of a major component (e.g. compressor)

Effects a betterment?: No

Treatment: Cost of replacement is a Variable Maintenance cost

Scenario 2 – Steam turbine

Service Life: Complete

Replacement: Major component (e.g. entire turbine)

Effects a betterment?: N/A – turbine is no longer serviceable

Treatment: Cost of replacement is not a Variable Maintenance cost

Scenario 3 – Steam turbine

Service Life: Partially complete (10,000 hours left)

Replacement: Major component (e.g. entire turbine)

Effects a betterment?: N/A – turbine is being replaced

Treatment: Cost of replacement is not a Variable Maintenance cost

Scenario 4 – Steam turbine

Service Life: Partially complete (20,000 hours left, turbine efficiency has decreased by 5% due to operation of the unit)

Replacement: N/A – applying a new coating

Effects a betterment?: Yes, the primary aim of applying the new coating is to make the turbine more efficient (*i.e.* decrease its heat rate).

Treatment: Some of the costs are Variable Maintenance costs while some are not. The percentage of costs that *do not* effect a betterment are Variable Maintenance costs, the remainder are not.

Other terminology for maintenance activities (e.g. preventative, predictive, corrective, routine, major, and minor maintenance costs)

The CAISO recognizes that there are number of different terms used by the industry to refer to different maintenance activities. In previous iterations of this proposal, the CAISO strove to develop definitions for these terms to aid our purposes. However, these terms ended up being contentious, difficult to define, and, ultimately, not useful for our end goals. We are aware of these terms and may indeed use them during O&M Adder negotiations but, for the purposes of the principles proposed herein, they will not be used. In particular, the distinction between major and minor maintenance does not have a standardized definition and is unnecessary if the principles above are applied appropriately.

Labor Costs

The cost of labor can be included in any of the cost components discussed above. The difficulty faced by market participants and the CAISO during negotiations is how to bucket the labor costs between the fixed and variable components. Consistent with the CAISO's proposed approach for

non-labor variable costs, labor costs should be considered variable if they vary with production of the Generating Facility. To determine this, the CAISO proposes that the labor costs must be linked with the associated operations and maintenance activity.

For example, regular, salaried staff may be involved in the performance of maintenance work on a turbine blade that needs to be repaired due to wear-and-tear from starting the unit. In this case, the actual dollar-value of the labor cost wouldn't fluctuate with output, run-hours, or starts because the employee is salaried. However, because the turbine blade needed to be replaced due to the variable operation of the unit, the component of the salaried worker's pay related to this repair should be considered variable and thus included in Variable Maintenance costs. If a contractor is brought in to perform this same work, the cost of the contractor would also be considered as a Variable Maintenance cost for the same reason.

In an opposite example, a contractor or personnel from another plant are brought in to perform routine, annual maintenance on the road leading to the facility (the wear-and-tear on which can be reasonably expected to *not* vary with MWh output, run-hours, or starts of the generating unit). Because the associated maintenance activity isn't affected by the operation of the unit, these costs would be considered to be Fixed Maintenance.

The CAISO recognizes that these are simplified cases and that the reality may be complicated by differences in accounting/payroll systems, business practices, etc. Accordingly, the CAISO encourages stakeholders to share their thoughts and bring up specific scenarios during this stakeholder process.

B) Default Variable Maintenance Costs Calculation

This appendix provides the narrative context for the calculation of the default Variable Maintenance (VM) costs used as the basis for the default Minimum Load and Startup O&M Adders. The detailed numerical calculations are included as an Excel spreadsheet attached separately on the webpage.

The proposed default VM values cover four technology types covering approximately 75% of resources with identifiable VM costs. The primary reason that the CAISO does not propose default VM values for all technology types is that there are not enough currently negotiated MMAs of those technology types. Without a sufficient number of negotiated MMAs, the CAISO is unable to cross-validate the external estimates to ensure their conservativeness.

The VM cost estimates are calculated using a five-step process:

- 1) Estimate variable maintenance costs using external sources
- 2) Determine which adder type (\$/run-hour, \$/start, or \$/MWh adder) is most appropriate for each technology type
- 3) Convert the variable maintenance costs to the appropriate adder type
- 4) Cross-validate the estimate from external sources against median major maintenance adder values to determine a default O&M Adder value
- 5) Using the default O&M Adder value, calculate a resource-specific O&M Adder

Step 1: Estimate variable maintenance costs using external sources

The CAISO uses external sources to estimate VM costs. As discussed above, the CAISO considers several criteria to ensure that the external sources used are appropriate. Ultimately, the CAISO uses four sources based on those criteria: NYISO (2010), NYISO (2016), EPA (2018), and EIA (2020).

The CAISO considers several criteria when selecting the external sources to use as the basis of the estimation of variable maintenance costs:

- **Definitional appropriateness:** The CAISO uses sources that have definitions of variable maintenance costs similar to the principles proposed above. Sources that specifically mention that their estimates include major maintenance costs, the largest component of variable maintenance costs, are preferred over those that did not. On this basis, the NYISO reports are the most consistent with the CAISO's proposed definitions for gas resources. Other sources considered usually did not specifically enumerate their definitions of VOM costs.
- **Geographical applicability:** Where possible, the CAISO used sources that apply to the CAISO/EIM footprint but, in some cases, the report does not apply specifically to these areas. In the case of the NYISO reports, the CAISO translates the labor component to WECC region-specific costs using a geographic weighting factor. In the case of the EIA and EPA reports, the CAISO assumes that the costs in the geographic area covered in those reports (*i.e.* the entire United States) is similar to those in the CAISO/EIM footprint.
- **Temporal applicability:** The CAISO uses only maintenance cost sources published within the past 10 years, as these would best reflect the recent changes to the energy system.
- **Technological appropriateness:** The CAISO only uses estimates from external sources if the turbine technology was representative of the resources in the CAISO/EIM footprint. The exception to this is hydro resources, where technology-specific data is typically not presented.
- **Credibility:** The CAISO chooses sources that are reputable, unbiased, and, ideally, from equipment manufacturers or operators. The CAISO prefers sources that were filed with regulatory bodies, such as public utility commissions, over those released for informational purposes only.

The CAISO considers certain technology types to be representative of the resources in the CAISO/EIM footprint. These representative technologies serve as the basis of the CAISO's determination of default values, both for VM and for VO costs. The CAISO recognizes that other turbine types are present in the CAISO/EIM operating areas. However, the technologies listed below are either the most common types or have the most readily accessible O&M cost information. The default VM and VO costs for these representative technologies apply to all resources within that technology group. For example, the default VM and VO costs for F-class CCGTs will apply to all CCGTs within the CAISO/EIM footprint.

The CAISO proposes that the following turbine technology types should be considered representative:

- CCGTs: F-class CCGTs
- (Frame) Combustion Turbines: F-class CTs
- Aeroderivative CTs: GE LM6000

The CAISO then gathers the cost data from the source documentation and converts the costs estimates to factor in differences in costs arising from temporal and geographic differences. For the hydro estimates, the CAISO converts the source documentation from a \$/MWh value to a \$/year value by

using a capacity factor of 33%. See tabs 1a, 1b, and 1c in the Supporting Calculations spreadsheet for the details of these calculations.

Step 2: Determine which adder type (\$/run-hour, \$/start, or \$/MWh adder) is most appropriate for each technology type

Once the external estimates have been converted to consistent units, the CAISO needs to determine which adder type is most appropriate as a default value for each technology type. Because the CAISO proposes to apply the default values to all resources within a technology type¹¹, the CAISO must determine a default adder type for each technology. This CAISO would like to stress that these adder types are the *default* adder type and, should a market participant wish for their adders to be expressed in a different format, they can negotiate a resource-specific O&M Adder with the CAISO.

The rationale for the CAISO's determination of the default adder type by technology is:

- **CCGTs:** the CAISO proposes a \$/run-hour default value based on the ratio of MMA costs which are currently reflected in a \$/run-hour format (~60%). Also, the CAISO believes that, on average, CCGT maintenance cycles will be driven by run-hours rather than starts. The NYISO report uses a ratio of run-hours/starts of 27 to determine whether a technology's maintenance cycle will be driven by starts or run-hours. If the ratio is below 27, the cycle will be driven by starts and vice versa. The CAISO/EIM operating data indicates that ratio is closer to 34 run-hours/start indicating that the cycle will be driven by run-hours.
- **[Frame] CTs:** the CAISO proposes to use a \$/start default value based on the set of existing MMAs. Approximately 99% of existing MMA costs are reflected in a \$/start format indicating that the maintenance cycles are typically driven by starts, rather than run-hours. Also, in its comments on the straw proposal, APS noted that approximately 90% of variable maintenance costs of its frame CTs are driven by starts.
- **Aeroderivative CTs:** the CAISO proposes a \$/run-hour default value based on the ratio of MMA costs which are reflected in a \$/run-hour format (~57%). This is consistent with the 2010 NYISO report that indicates that maintenance cycles for aeroderivative CTs are driven by run-hours.
- **Hydro:** the CAISO proposes a \$/run-hour default value. MMA costs are relatively evenly split between \$/run-hours and \$/start for Hydro resources. Based on the CAISO's recent experience, the CAISO believes that Hydro resources are more likely to incur costs based on run-hours, rather than starts. This is because most hydro resources are modelled as non-MSGs despite having multiple turbines. Accordingly, many dispatches between Pmin and Pmax, may actually result in additional turbines being committed. The CAISO market will not recognize these as starts/transitions, meaning that a \$/start adder will be used much less frequently.

Step 3: Convert the variable maintenance costs to the appropriate adder type

The external cost estimates are not presented in the adder type format that is proposed in Step 2. For gas resources, the CAISO performs a simple conversion using the starts/cycle or run-hours/cycle conversion factors found in the NYISO source documentation. For hydro resources, the conversions needed are slightly more complicated and involve operating data (run-hours per year) from the CAISO

¹¹ Except for resources that already have a negotiated MMA. See *Implementation of new default values* section for more discussion of how the default values will be applied.

and EIM areas. See the Step 3 tab in the Supporting Calculations spreadsheet for the details of these calculations.

Step 4: Cross-validate the estimate from external sources against median major maintenance adder values to determine a default O&M Adder value

As noted in the main body of the paper, a key principle affecting the CAISO's estimates is that the estimates need to be sufficiently conservative while also still attractive for use in lieu of negotiated values. To balance these two competing goals, the CAISO proposes to limit the proposed default VM cost values to the median of currently approved MMA values. For technology types in which the external sources exceed the median MMA values, the CAISO will use the median of the MMA values. The median MMA value is used in lieu of the mean or an interpolated¹² to mitigate the impact of outlier MMA values. The median value was calculated for only those technology types with a sufficient number of MMAs¹³. The CAISO also assesses whether the resources with MMAs are a reasonable cross-section of the resources within the CAISO/EIM footprint, noting that the resources with MMAs were substantially in line with the bulk of resources in the CAISO markets.

This approach has two important implications. The first is that the CAISO can only calculate robust default O&M adders for four technology types. Only these four technology types have a sufficient sample size of existing MMAs against which the CAISO could reasonably check the estimates. The second implication is that the CAISO cannot share the detailed calculations of the median MMA values. Doing so may result in releasing confidential maintenance cost data. The CAISO recognizes that this is not the optimal solution but it is one driven by confidentiality requirements.

As mentioned above, the MMA values give the CAISO useful information about resource-specific maintenance cost data. However, the CAISO believes that using the MMA values as a way to cross-validate the estimates, rather than as the basis of the estimates themselves, is the most appropriate methodology. We believe this because relying solely on the MMA values may result in circularity. Only resources with costs higher than the default values will negotiate with the CAISO and these negotiated values would then become inputs into the calculation of the default values, resulting in a feedback loop of higher and higher default values. The CAISO's use of external estimates breaks this feedback loop by serving as an independent input into the calculation.

The CAISO presents the proposed default O&M Adders in Table 6. Table 6 also shows the median MMA values for those technologies where the external estimate exceed the median MMA values. For the technologies where the median value negotiated MMAs exceed the external estimates, the CAISO is not disclosing these values for confidentiality purposes. The far right column shows the proposed default O&M Adder calculated as follows for each technology type:

$$\text{Default O\&M Adder} = \min(\text{External Estimate VM Costs}, \text{Median MMA Value})$$

¹² The CAISO proposed using an interpolated value using a simple linear regression in the revised straw proposal. The use of median values in this draft final proposal is a change in methodology from the revised straw proposal.

¹³ The CAISO concludes that a sufficient number of MMAs was that the technology type has to have at least 20 resources with negotiated MMAs based on actual costs, rather than PPAs or LTSAs. For multi-stage generators, the CAISO uses only the first configuration or, in the case of CCGTs, the 1X1 configuration for the purposes of this calculation.

Table 6 – Proposed default O&M Adder values

Technology Type	External Estimate VM Costs	Median MMA Values	Default O&M Adders	Units
CCGTs	1.74	-	1.74	\$/run-hour per MW
[Frame] CTs	52.13	-	52.13	\$/start per MW
Aeroderivative CTs	4.38	-	4.38	\$/run-hour per MW
Hydro	1.12	0.65	0.65	\$/run-hour per MW

Step 5: Using the default O&M Adder value, calculate a resource-specific O&M Adder

The CAISO proposes to use of the capacity of the resource (*i.e.*, its Pmax) to scale default O&M Adder to be a resource-specific O&M Adder. If the resource is a multi-stage generator (MSG), the CAISO proposes to calculate the resource-specific O&M Adder using the Pmax of each configuration to reflect the additional costs of wear-and-tear of operating of each configuration. The resulting unit-specific adder calculation is proposed as follows:

$$\text{Resource-specific O\&M Adder} = \text{Default O\&M Adder} * \text{Resource's Pmax}$$

Or if the resource is a multi-stage generator (MSG):

$$\text{Configuration-specific O\&M Adder} = \text{Default O\&M Adder} * \text{Configuration's Pmax}$$

Resource-specific O&M Adder – Example calculations

To help illustrate how the resource-specific Minimum Load and Startup O&M Adders will be calculated, the CAISO includes some examples below:

Non-MSG Example

Table 7 – Non-MSG Example

Parameter	Value
Technology Type	Aeroderivative CT
Pmax of resource (MW)	50
Proposed default O&M Adder (\$/run-hour per MW)	4.38

$$\begin{aligned} \text{Resource-specific Minimum Load O\&M Adder} &= \text{default O\&M Adder} * \text{Pmax of resource} \\ &= \$4.38 * 50 \\ &= \$219/\text{run-hour} \end{aligned}$$

MSG Example

Table 8 – MSG Example

Parameter	Value
Technology Type	Aeroderivative CT
Pmax of Configuration 1 (MW)	50
Pmax of Configuration 2 (MW)	100
Proposed default O&M adder (\$/run-hour per MW)	4.38

Configuration 1

Configuration-specific Minimum Load O&M Adder = default O&M Adder * Pmax of Config 1
= \$4.38 * 50
= \$219/run-hour

Configuration 2

Configuration-specific Minimum Load O&M Adder = default O&M Adder * Pmax of Config 2
= \$4.38 * 50
= \$438/run-hour

C) Updated proxy cost formulas

This section clarifies the proposed proxy cost formulas under this initiative. In this case, the primary formulas being proposed for modification are the DEB under the Variable Cost option and the Minimum Load Bid Cap and the Startup Bid Cap under the Proxy Cost option. The CAISO is also proposing updates to the formulas Maximum Registered Minimum Load Costs and Maximum Registered Start-up Costs under the Registered Cost option. Those changes are substantially the same as those proposed for the Proxy Cost option and, as the Registered Cost option is much less commonly used than the Proxy Cost option, the CAISO excludes these for brevity's sake.

Variable Cost Default Energy Bid formula

Current DEB =

$1.10 * [(Incremental\ Heat\ Rate/1000 * Fuel\ Region\ Price) + VOM\ adder + GMC\ adder + (Incremental\ Heat\ Rate/1000 * Emission\ Rate * GHG\ Allowance\ Price)] + FMU\ adder\ (if\ eligible) + Variable\ Energy\ Opportunity\ Cost\ (if\ eligible)$

Proposed Variable Cost DEB =

$1.10 * [(Incremental\ Heat\ Rate/1000 * Fuel\ Region\ Price) + Energy\ O\&M\ adder + GMC\ adder + (Incremental\ Heat\ Rate/1000 * Emission\ Rate * GHG\ Allowance\ Price)] + FMU\ adder\ (if\ eligible) + Variable\ Energy\ Opportunity\ Cost\ (if\ eligible)$

Proxy Minimum Load Cost formula

Current MLC =

$1.25 * [(Minimum\ Load\ Heat\ Rate/1000 * Pmin * Fuel\ Region\ Price) + (VOM\ adder * Pmin) + (GMC\ adder * Pmin) + (Pmin * Minimum\ Load\ Heat\ Rate/1000 * Emission\ Rate * GHG\ Allowance\ Price) + Major\ Maintenance\ Adder] + Minimum\ Load\ Opportunity\ Cost\ (if\ eligible)$

Proposed MLC =

$$1.25 * [(Minimum\ Load\ Heat\ Rate/1000 * Pmin * Fuel\ Region\ Price) + (Energy\ O\&M\ adder * Pmin) + (GMC\ adder * Pmin) + (Pmin * Minimum\ Load\ Heat\ Rate/1000 * Emission\ Rate * GHG\ Allowance\ Price) + Minimum\ Load\ O\&M\ Adder] + Minimum\ Load\ Opportunity\ Cost\ (if\ eligible)$$

Proxy Startup Cost formula

Current SUC =

$$1.25 * [(Start-Up\ Fuel * Fuel\ Region\ Price) + (Start-Up\ Energy * Electricity\ Price\ Index) + (Pmin * Start-Up\ Time\ Period * GMC\ adder / 2) + (Start-Up\ Fuel * GHG\ Emission\ Rate * GHG\ Allowance\ Price) + Major\ Maintenance\ Adder] + Startup\ Opportunity\ Cost\ (if\ eligible)$$

Proposed SUC =

$$1.25 * [(Start-Up\ Fuel * Fuel\ Region\ Price) + (Start-Up\ Energy * Electricity\ Price\ Index) + (Pmin * Start-Up\ Time\ Period * GMC\ adder / 2) + (Start-Up\ Fuel * GHG\ Emission\ Rate * GHG\ Allowance\ Price) + Startup\ O\&M\ Adder] + Startup\ Opportunity\ Cost\ (if\ eligible)$$

D) Implementation details

While it is not customary to discuss implementation details within a draft final proposal, the CAISO believes that some discussion is warranted based on stakeholder questions throughout the initiative. These issues fall into mainly three categories: 1) how existing negotiated MMA and VOM values will be treated, 2) how the CAISO intends to handle negotiation of the newly proposed O&M Adders prior to and after the implementation of the proposal, and 3) other miscellaneous implementation details.

Treatment of existing negotiated MMA and VOM values

In general, the CAISO proposes to allow participants to grandfather in the negotiated MMA values and VOM adder values upon the implementation of this initiative. Under the proposed framework, the existing MMAs will automatically convert to being Minimum Load and/or Startup O&M Adders keeping the same \$/run-hour or \$/start values. Similarly, the CAISO proposes to allow participants to grandfather in the existing negotiated VOM adders upon implementation, with the existing negotiated VOM automatically converting to being Energy O&M Adders keeping the same \$/MWh values.

Upon implementation, some participants with resources that have grandfathered O&M Adders (*i.e.* legacy MMAs or negotiated VOM adders) may wish to negotiate the O&M Adders under the new cost framework. In such cases, the CAISO proposes to allow only two options: 1) negotiate all O&M Adders as a package¹⁴, terminating the grandfathered O&M Adders or, 2) negotiate only those O&M Adders that the resource requests under the new cost framework and set the remaining O&M Adders to the newly

¹⁴ For example, a resource has a legacy negotiated VOM adder but no legacy MMAs. Under this option, if they wish to negotiate a Minimum Load O&M Adder, they would be required to negotiate both the Minimum Load O&M Adder and a new Energy O&M Adder to “replace” the legacy negotiated VOM adder.

proposed default O&M Adder values. This approach will eliminate the risk of double counting of costs between the “grandfathered” O&M Adders and the new O&M Adders that may arise from the proposed changes to the cost framework and principles.

Table 8 – Proposed implementation approaches

Situation	Proposal
Resources <u>with no</u> negotiated MMA	Upon implementation, these resources will be <i>automatically</i> assigned a resource-specific Minimum Load or Startup O&M Adders based on their technology group, Pmax, and the default values presented in Table 1.
Resources <u>with a</u> negotiated MMA	<p>Upon implementation, these resources will be allowed to keep their existing MMA values. The CAISO will not automatically switch any resources with a previously negotiated MMA over to the newly proposed default Minimum Load or Startup O&M Adders. Instead, the MMA values will be “converted” to a negotiated Minimum Load and/or Startup O&M Adder. This means that their Minimum Load and/or Startup O&M Adders under the new framework will have the same values as their legacy Minimum Load or Startup MMAs.</p> <p>However, as noted in Attachment L.6 of the BPM for Market Instruments, circumstances may arise that would trigger a review or renegotiation of a legacy MMA. This includes situations such as changing from a non-MSG to an MSG, changes in technology type, change of scheduling coordinators, etc. In such cases, the CAISO has the discretion to terminate the existing negotiated value and negotiations would then take place under the new cost principles.</p> <p>If the participant wishes to use the new default Minimum Load or Startup O&M Adders, they can contact the CAISO to switch over to the new values. The negotiations after that point would be carried out under either of the two options noted above this table.</p>
Resources with a <u>default</u> VOM adder	Upon implementation, these resources will be <i>automatically</i> assigned to the default Energy O&M Adder value based on their technology group.
Resources with <u>negotiated</u> VOM adder	<p>Upon implementation, these resources will be allowed to keep their existing negotiated VOM adder values. The CAISO will not automatically switch any resources with a previously negotiated VOM adder over to the newly proposed default Energy O&M Adder. Instead, the VOM values will be “converted” to a negotiated Energy O&M Adder. This means that their Energy O&M Adder under the new framework will have the same value as their legacy negotiated VOM adder.</p> <p>However, as noted in Section 4.1 of the BPM for Market Instruments, circumstances may arise that would trigger a review or renegotiation of a legacy negotiated VOM adder. This includes situations such as changing from a non-MSG to an MSG, changes in technology type, etc. In such cases, the CAISO has the discretion to terminate the existing negotiated</p>

	<p>value and negotiations would then take place under the new cost principles.</p> <p>If the participant wishes to use the new default Energy O&M Adder, they can contact the CAISO to switch over to the new value. The negotiations after that point would be carried out under either of the two options noted above this table.</p>
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As DMM noted in their comments to the straw proposal, the scheduling coordinators for some resources do not have access to the documentation necessary to apply for negotiated maintenance reference values. Typically, this is because these resources are held under a power purchase agreement. In such cases, the resource should use the default values until such a time that the documentation can be provided. If these resources have existing negotiated MMAs or VOM adders, the CAISO proposes to allow these values to be grandfathered in. A resource that wishes to increase their negotiated values under the new cost framework can do so once they can provide the appropriate documentation. The CAISO does not wish to discourage SCs from submitting O&M Adder applications. Accordingly, simply just submitting an application for an increase in their grandfathered values will not trigger an automatic switch to the default values.

Negotiations of adders during the time surrounding the implementation this proposal

Under this proposal, CAISO proposes to allow market participants to negotiate any of the O&M Adder values. This process will be analogous to the current process for negotiating MMAs or VOM adders. In order to plan for a potential influx of negotiations requests around the implementation time, this section outlines the CAISO proposed plan.

The dates discussed below should be considered only as a reference based on the current and planned schedule.

The proposed implementation plan has two key dates: the date on which the newly proposed O&M principles will go into place and the date on which the new default O&M Adders will be effective. The CAISO expects the explicit principles to be effective on 5/1/2021; this will allow the CAISO and market participants the time to process negotiated O&M Adder values before the next key date. The next key date is 10/1/2021, when the CAISO proposes to implement the new default O&M Adder values.

The CAISO proposes a two-phase approach to handling the negotiations:

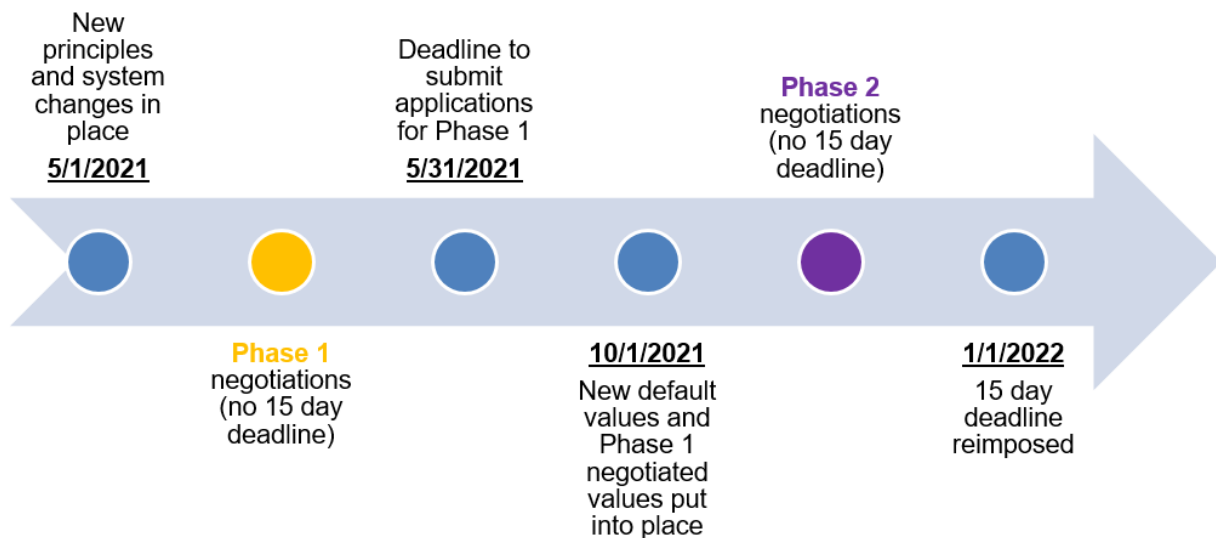
In Phase 1, participants will have a time window between 5/1/2021 and 5/31/2021 to apply for O&M Adders. CAISO will aim at completing their negotiations before 10/1/2021, assuming no major disputes are raised in the negotiation process. Phase 1 is when the CAISO would like most applications to be handled, as this would reduce the pressure on the CAISO and market participants by spreading the negotiations over a multi-month period. These negotiations would be handled on a first-come first-served basis¹⁵. With the potential for a higher volume of

¹⁵ The exception to this would be certain cases that require more immediate negotiations. Examples of these cases are if a resource changes to a new SC or a new resource enters the market. In such cases, the CAISO expects to negotiate these applications on a more expedited basis.

negotiations, CAISO expects to relax the required 15-day period discussed in the “Other miscellaneous implementation details” below during this period.

Phase 2 will apply to applications submitted between 6/1/2021 and 9/30/2021. For applications submitted during this period, the CAISO does not commit to completing the negotiations by 10/1/2021. While the CAISO will do its best to work with market participants to complete negotiations before 10/1/2021, the potentially large number of negotiations may be overly difficult to complete before that date. These negotiations would also be handled on a first-come first-served basis and would not be subject to the 15-day period discussed in the “Other miscellaneous implementation details” below. On 1/1/2022, the 15-day period would be reimposed and negotiations after that date would carry on under normal circumstances.

Figure 4 – Proposed Implementation Timeline



The CAISO expects to provide detailed BPM guidance early in 2021 so that market participants can begin gathering O&M cost data far in advance of 5/1/2021. In this guidance, the CAISO will clarify the expectation for documentation to be provided. Understanding that these negotiations are a two-sided affair and represent an investment of time and resources, the CAISO welcomes comments on this section of the proposal as well.

Other miscellaneous implementation details

Negotiation timelines

The CAISO also proposes to modify the portion of the Tariff that subjects the CAISO to a 15-day *calendar* day period in which the CAISO must review and respond to negotiation applications and questions. This 15-day period is intended to provide market participants with a timely response to their MMA negotiation application. The CAISO proposes to update in which the CAISO must review and respond to O&M Adder applications and questions that the time period be 15 *business* days.

In reaction to this, the CAISO also proposes to change the 30 calendar day period during which market participants cannot renegotiate their O&M Adders after they have been accepted. The CAISO proposes to extend this to a 30 *business* day period.

Triennial review

The CAISO proposes to review the default O&M Adders once every three years to ensure their appropriateness. During these triennial reviews, the CAISO will consider factors such as inflation or changes in technology. The next triennial review is slated for 2021 and the cost year used in this proposal is 2019. Accordingly, the CAISO expects the 2021 triennial review to be a considerably abbreviated review, with an incremental review of the values, but likely not the cost framework, being expected in 2024.

RMR resources

The CAISO does not intend this initiative to alter the treatment of reliability-must-run (RMR) resources. For new RMR resources, the CAISO claws back MMAs from market revenues in the financial settlement of the RMR Units for the variable costs recovered through the market. This mechanism ensures that fixed payments made to RMR owners, which include reimbursement for major maintenance costs¹⁶, if applicable, and the revenues earned by RMR owners from the CAISO's markets are not duplicative. RMR resources also recover their minor Variable Maintenance and Variable Operations Costs through the VOM adder that is included in RMR resources' market revenues. This initiative does not propose to alter this treatment and thus we do not expect to modify the pro-forma RMR agreement as a result of this initiative.

E) Default Wind Variable Operations Costs Calculation

Based on stakeholder feedback on the revised straw proposal, the CAISO determined that a sufficient basis exists for the development of default Variable Operations costs for wind resources. These cost estimates are used to calculate the default Energy O&M Adder for wind resources. They represent the CAISO's estimate of variable royalty payments to the owners of the land on which wind turbines are situated. The calculation has two core components: 1) an estimate of the gross revenues received by wind resources, expressed in \$/MWh and 2) an estimate of the royalty payments due to landowners, expressed in the percentage of gross revenues.

The CAISO estimates the gross revenues received by wind resources by using 2019 CAISO average 15-minute prices. This estimate, derived from DMM's 2019 Annual Report on Market Issues and Performance, is \$37.50/MWh. Because wind resources are not producing at full capacity on a 24/7 basis, we multiply the price by a capacity factor to arrive at gross revenues. Using CAISO/EIM operating data from 2019, the CAISO estimates a capacity factor for wind resources at 25%. This value, $\$37.50/\text{MWh} * 25\% = \$9.38/\text{MWh}$, approximates the gross revenues received by wind resources, on average, during the study year 2019.

Once an estimate of the gross revenues received by wind resources has been determined, the CAISO applies a percentage rate to these revenues to estimate the default Variable Operations costs. This percentage represents the variable payments made by wind resource owners to the owners of the land on which wind turbines are situated. Because this cost varies with the MWh production of the resource

¹⁶ For RMR resources, the major maintenance costs are spelled out explicitly in the RMR contract, meaning that they can be easily identified. This is different than for other non-RMR resources where a distinction between major and minor Variable Maintenance costs are not made.

and is not included elsewhere in the proxy costs (e.g. maintenance costs, greenhouse gas allowance costs, fuel costs, and grid management charges), this is properly considered a VO cost. The CAISO believes that a reasonable percentage to apply is 3%. The CAISO corroborated this percentage using multiple sources, the primary source being from the New York State Energy Research and Development Authority (NYSERDA). The final estimate for Variable Operations costs for wind resources is found by multiplying the gross revenues of \$9.38/MWh by 3% to arrive at a value of \$0.28/MWh.

We also recognize that not all wind resources face royalty payments and not all royalty payments are made on a variable (*i.e.* percentage of gross revenues) basis. However, the use of the generally accepted 3% benchmark estimate and the relatively low \$/MWh value (in comparison to other Variable Operations costs estimates), the CAISO believes that we have a sufficient basis to propose a conservative default Variable Operations cost estimate.

F) Default Variable Operations Costs Report by Nexant

See the report starting on the following page. No changes were made to Nexant's report since the revised straw proposal, hence some of the language used in Nexant's report may be slightly inconsistent with the language in the remainder of the draft final proposal. The core goal of the Nexant report is to provide estimates of Variable Operations costs; that has not changed between versions of this paper.

REPORT



Reimagine tomorrow.



Variable Operations Costs Report - Version 2

Submitted to: California Independent System Operator

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1 Introduction and Background

1.1 Objectives and Requirements

The CAISO engaged Nexant to assist them to review and update the variable operations and maintenance cost values that are used in their market processes. The CAISO's overall objectives for this engagement are as follows:

- 1) To perform a review of the variable operations costs (VO) of generators in order to help ensure that the cost inputs used in CAISO markets are reasonable reflections of expected costs.
- 2) To revise the current technology types and default values for VO in its Tariff to reflect the current technology and technology-specific VO costs in the Western Interconnection.

In addition, listed below are a few other requirements that went into the development of the VO default cost values:

- VO values should be developed for generator types that have a significant market presence in the Western Interconnection
- VO values should adhere to the CAISO's definition of Variable Operations Costs discussed below.
- Since VO values developed will be used by the CAISO as default values in the CAISO market they should be representative of a large fraction of the generators in the class - for generators whose variable operations costs are different the default VO value, the CAISO is expected to continue its past practices of working with generator owners to develop generator-specific VO values.
- To the extent possible, VO values should be developed using publicly available information.
- The VO costs developed should be representative of the costs in the year 2019. To accomplish this, the project included the development of a methodology to escalate cost data from years prior to 2019 (i.e. in 2009 dollars) to cost in 2019 dollars.

On December 26, 2018, Version 1 of this report was completed and made available to stakeholders. It was presented to stakeholders on a conference call on January 8, 2019 and comments on the report were solicited by the CAISO following the call. This report (Version 2) is part of the overall actions that the CAISO has taken in response to these comments and to additional stakeholder comments regarding cost adders received after the January 8, 2019 stakeholder call. The CAISO has developed a summary of their overall approach to operations and maintenance costs/adders which can be found on the CAISO website.

1.2 Report Overview

This report summarizes the work that was performed to the meet objectives while meeting the requirements listed above – namely the review and potential revision of the default VO values used in the CAISO market.

This draft report is organized into the following sections:

- **Section 2:** Cost Definitions, Data Sources and Methodology for Cost Development
- **Section 3:** Cost Information for Generating Plants

2 Cost Definitions, Data Sources and Methodology for Cost Development

2.1 Cost Definitions

We note that in the course of searching for data and developing the various costs factors, there are no standard definitions for what operations and maintenance costs should be considered variable vs. what costs should be considered fixed. Further, there are no standard definitions regarding what costs should be considered variable with respect to energy production (MWh) or plant starts or plant operating hours. This report utilizes the following CAISO definitions (directly or indirectly) in characterizing cost information in this report. They are intended to be consistent with the CAISO's definition related to VO costs as they are designed to be used in the CAISO market processes.

2.1.1 Variable Operations Costs (VO)

Variable Operations (VO) costs are the portion of the operations costs that are a function of the level energy production (MWh) of the generating unit over any period of interest. In other words, the portion of operations costs (excluding fuel costs) that varies directly with the MWh production of the generating unit. To be consistent with how the VO costs are used in the CAISO market, the VO values developed in this report include only costs associated with consumables and waste disposal. The VO values do not include any form of maintenance costs.

All references to VO cost in this report are based upon the CAISO definition unless otherwise stated.

Examples of costs that are included in the VO values per the CAISO definition are costs for:

- Raw water
- Waste and wastewater disposal expenses
- Chemicals, catalysts and gases
- Ammonia for selective catalytic reduction
- Lubricants whose use depends upon energy production
- Consumable materials and supplies

Other cost categories that are often referred to in the industry include major maintenance, other maintenance and fixed operations costs, none of which are included in the VO values in this report.

2.2 Data Sources

2.2.1 General

Generally, public data that could be used to develop O&M values often come from reports that were developed for generation planning or analysis. As such, they are focused heavily on capital costs and the O&M costs are normally treated at a high level. In these sources, O&M cost is not generally segregated into categories that are useful to developing a CAISO VO default value. For developing VO costs that are consistent with the CAISO market design, emphasis was placed upon finding data sources that segregated the costs related to consumables and waste disposal from other costs, making it possible to more accurately estimate VO costs for use in the CAISO market. The various sources referred to in the course of developing the default VO values are listed below.

2.2.2 Independent System Operators' Cost of New Entry (CONE) Study Reports

Independent System Operators (ISOs) that operate capacity markets in the US (e.g. New York ISO, PJM, and ISO New England) periodically perform Cost of New Entry (CONE) studies to develop the demand curve for their capacity auctions. Typically, the ISOs hire an Independent Consultant to develop the inputs for the demand curve, including the cost of a new peaking unit. These studies involve the detailed development of construction cost estimates, operating cost data and plant operating characteristics by an engineering firm or based on inputs from an engineering, procurement and construction (EPC) company. In these studies, the CONE for two types of plants are typically developed – peaking plants which include simple cycle aeroderivative combustion turbines, frame combustion turbines and reciprocating internal combustion engines (RICE) and combined cycle power plants using 1x1 or 2x1 configurations of frame combustion turbines.

In addition to capital costs for new units, the fixed O&M costs and variable O&M costs are also developed in these studies. Typical fixed plant expenses include routine O&M, and administrative and general costs. Variable O&M costs are directly related to plant electrical generation and start-ups and consist of two components. One variable operating cost component includes the consumables such as ammonia for the Selective Catalytic Reduction (SCR), chemicals, and lube oil for the RICEs, water, and other production-related expenses including SCR and oxidation catalyst replacement. This component is similar to the CAISO VO definition. Major maintenance costs (parts and labor) associated with gas turbine, steam turbine, and HRSG are provided as a separate line item in these reports but are not included in the VO values developed in this report.

The CONE reports for NYISO and PJM can be accessed using the links below. NYISO and PJM have performed these CONE studies every three years.

<https://www.nyiso.com/installed-capacity-market>

(Note: The reports can be accessed by clicking on “Installed Capacity Data”, “Reference Documents” and “2017-2021 Demand Curve Reset”.)

<https://www.pjm.com/markets-and-operations/rpm.aspx>

(Note: The most recent report can be accessed under “External Reports” on this page. Earlier reports can be obtained by searching for “Brattle CONE report” using the search function on this page.)

2.2.3 Sargent and Lundy

Sargent & Lundy published the “New Coal Fired Power Plant Performance and Cost Estimates report” in August 2009. This one-time report which was produced for the EPA provides a detailed breakdown of the variable O&M components for coal plants in a manner that is consistent with the CAISO VO definition. This disaggregation of O&M costs allows for the calculation of VO associated with consumables and waste only which enables a bottom-up calculation of VO values. This data is used for the many coal fueled power plants in the report as well as a reference to other fossil fueled plants with similar water and emission control systems.

<https://www.epa.gov/sites/production/files/2015-08/documents/coalperform.pdf>

2.2.4 EPA Compilation of Air Pollutant Emissions Factors (AP-42)

Compilation of Air Pollutant Emissions Factors (AP-42) has been published by EPA since 1972 as the primary compilation of EPA's emission factor information. It contains emissions factors and process information for more than 200 air pollution source categories. A source category is a specific industry sector or group of similar emitting sources. The emissions factors have been developed and compiled from source test data, material balance studies, and engineering estimates. Data from this source was used to compare/develop estimates for consumables related to emission controls for various generation types including coal, natural gas and biomass.

https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

2.2.5 DOE Utility-Scale Solar Reports

The DOE Utility-Scale Solar Report, published annually since 2011, provides an overview of developments and trends in the U.S. solar power market. This report summarizes the trends in the solar industry related to installation, technology, performance, cost and solar power purchase agreement (PPA) prices. In addition to capital costs, this report also provides a detailed summary of O&M costs. Berkeley Lab, the primary author of this report, has compiled limited O&M cost data for 40 solar projects in the United States, totaling 800 MW and with commercial operation dates of 2011 through 2016. Although the data sources do not all clearly define what items are included in O&M costs, in most cases the reported values include the costs of wages and materials associated with operating and maintaining the solar project, as well as rent. Other ongoing expenses, including general and administrative expenses, taxes,

property insurance, depreciation, and workers' compensation insurance, are generally not included.

https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_report.pdf

2.2.6 DOE Wind Technologies Market Reports

The DOE Wind Technologies Market Report published annually since 2005 provides an overview of developments and trends in the U.S. wind power market. These reports summarize the trends in the wind industry related to installation, technology, performance, cost, wind power price and policies. In addition to capital costs, this report also provides a detailed summary of O&M costs. Berkeley Lab, the primary author of this report, has compiled limited O&M cost data for 164 installed wind power projects in the United States, totaling 14,146 MW and with commercial operation dates of 1982 through 2016. These data cover facilities owned by both IPPs and utilities, although data since 2004 are exclusively from utility-owned projects and so may not be broadly representative. The treatment of O&M costs for wind projects is similar to the treatment of O&M costs for solar projects as described in the previous section in that data sources do not all clearly define what items are included in O&M costs but generally include or exclude the same type of costs as listed in the previous section.

https://www.energy.gov/sites/prod/files/2018/08/f54/2017_wind_technologies_market_report_8.15.18.v2.pdf

2.2.7 NREL O&M Cost Reports

The National Energy Renewable Laboratory periodically publishes detailed reports on the O&M costs associated with wind and solar PV plants. These reports give a detailed breakdown of the O&M cost components for wind and solar plants and can be used to determine the costs that are variable and fixed as per CAISO's definition.

<https://www.nrel.gov/docs/fy08osti/40581.pdf>

<https://www.nrel.gov/docs/fy17osti/68023.pdf>

2.2.8 EIA Annual Energy Outlook Reports

The U.S. Energy Information Authority (EIA) has been publishing the Annual Energy Outlook (AEO) since 1979. Projections for the AEO report are obtained from the North American Energy Modeling System (NEMS), a model developed and maintained by the Office of Energy Analysis of the U.S. EIA. NEMS has several modules of which the Electricity Market Module (EMM) is one. The NEMS Electricity Market Module (EMM) represents the capacity planning, dispatching, and pricing of electricity. Based on fuel prices and electricity demands provided by the other modules of NEMS, the EMM determines the most economical way to supply electricity, within environmental and operational constraints. The cost and performance characteristics of new generating technologies are inputs to the EMM electricity capacity planning submodule. EIA maintains an archive (<https://www.eia.gov/outlooks/aeo/archive.php>) of assumptions used in the NEMS model. These assumptions are available for the years 1996 and later.

Every three years on average, the EIA commissions an external consultant to update current cost estimates for certain utility scale electric generating plants. The external consultant reports from 2010, 2013, and 2016 are available on EIA's website. The focus of these studies is to gather information on the engineering, procurement and construction costs, operating costs, and performance characteristics for a wide range of generating technologies. Where possible, costs estimates are based on information derived from actual or planned projects known to the consultant.

Non-fuel operations and maintenance (O&M) costs associated with each of the power plant technologies are also evaluated in these external consultant studies. The O&M costs that do not vary significantly with a plant's electricity generation are classified as fixed, while the costs incurred to generate electricity are classified as variable. However, in these reports, all the major maintenance costs are included under variable O&M costs.

EIA scales the costs using a cost adjustment factor for the years that an external consultant's report is not produced. The cost adjustment factor, based on the producer price index for metals and metal products, allows the overnight costs (capital costs) to fall in the future if this index drops, or rise further if it increases. It should be noted that the methodology for calculating the various costs has been consistent only for the past 10 years. Older data, while available should be used with caution since the methodology used for classifying various costs followed a different approach. In addition, the most recent studies are generally high level and do not go into the detailed engineering analysis that one finds in the NY CONE studies or the Sargent and Lundy coal studies discussed above.

2.2.9 Geothermal H₂S Abatement Costs

A paper titled "Geysers Power Plant H₂S Abatement Update" by John Farison, Brian Benn, Brian Berndt, Calpine Corporation; was published in the Geothermal Research Council Transactions, Vol. 34, 2010. The paper deals with hydrogen sulfide treatment at the Geysers Power Plant in northern California including effluent abatement and the operations and maintenance costs associated with the H₂S treatment. A link to the paper is included below. This source was used to develop default VO values for geothermal generating units.

<https://www.geothermal-library.org/index.php?mode=pubs&action=view&record=1028816>

2.2.10 Black & Veatch

This report (COST AND PERFORMANCE DATA FOR POWER GENERATION TECHNOLOGIES, 2010) was prepared for the National Renewable Energy Laboratory NREL (NREL) for comparison of cost of conventional technologies vs. renewable technologies. NREL contracted Black & Veatch to provide the power generating technology cost and performance estimates that are described in this report. This data was used to compare against other sources of cost for renewable generation plants. Some of the cost data in this report is based upon EIA reports.

<https://www.nrel.gov/docs/fy11osti/48595.pdf>

2.2.11 Wood Fuels Handbook

Report prepared by Dr. Nike Krajnc and published by the Food and Agriculture Organization of the United Nations (FAO-UN), 2015. This report provides data on various biomass fuels and their detailed analysis. This handbook was used in estimating the Biomass VO cost.

<https://roycestreeservice.com/wp-content/uploads/Wood-Fuels-Handbook.pdf>

2.2.12 Lazard's Levelized Cost of Energy

Lazard regularly publishes LCOE reports that include capital and O&M costs. However these reports do not provide detailed breakdown of cost components. This source was used as a source of O&M data for nuclear plant O&M costs.

<https://www.lazard.com/perspective/levelized-cost-of-energy-2017/>

2.2.13 EPA Combined Heat and Power

EPA published a Catalogue of CHP Technologies in partnership with ORNL and ICF in September 2017. It provides O&M cost breakdown for various generation technologies, including IC engines.

https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf

2.2.14 Parson Brinkerhoff Report

Parson Brinkerhoff Report for the CCS O&M costs - July 2012 by Parsons Brinkerhoff for IEA Environmental Projects, 2012. This report estimates O&M costs of carbon capture from combined cycle plants. Developed for IEA, it was used to estimate the cost of Carbon Capture and Sequestration costs, if any.

https://ieaghq.org/docs/General_Docs/Reports/2012-08.pdf

2.2.15 IRENA (Renewable Power Generation Cost Reports)

The O&M cost review for some solar, wind, and small and large hydro plants were performed using the IRENA Renewable Power Generation Cost Reports. These reports are published regularly by IRENA and are developed from a cost database that includes 15000 data points for LCOE from projects around the globe, representing over 1000 gigawatts (GW) of power generation capacity. An additional auctions database encompasses over 7,000 projects with nearly 300 GW of capacity. A link to the report is included below.

<https://www.irena.org/publications/2018/jan/Renewable-Power-Generation-Costs-in-2017>

2.3 Methodology Used to Develop VO Costs

The overall approach taken to develop the VO cost estimates was to first find public sources, if possible, that included VO type information that is consistent with the CAISO's definition of VO costs. When possible this was done with sources that disaggregated VO costs from other types of O&M costs (major and minor maintenance and fixed costs) thus allowing a type of bottom up

estimation methodology. In cases where such data was found, the next steps was to revise the data, if required, to reflect CAISO's requirement of establishing VO default values that are representative of the VO costs that would be applicable to many of the units for this type of generator. As indicated earlier, the expectation is that if there are plants that have VO costs different than the default VO values presented here, that the plant owner/operator can approach the CAISO to develop a unit specific VO value.

It was possible in the case of most generation types to use the approach previously described. In a few cases when a bottom up approach was not possible, VO costs were estimated using aggregated O&M costs that were then partially disaggregated into VO and other costs using engineering judgement.

Finally, these VO costs which represent data for years prior to 2018 were adjusted to be representative of the costs in the year 2019 – the target year for all potential revised VO values. This simple methodology used for escalating a cost from a prior year to 2019 is described below.

2.3.1 Escalating Costs to 2019 Target Year

We reviewed the various cost components in the VO and the range of types of costs in various VO values and observed that these costs can include a range of chemical costs, a range of disposal costs, some labor costs and some disposal fees.

Based upon that review of the components of VO costs and their escalation over time, it was decided that the best, as well as the simplest approach to escalate costs from a previous year (for example, 2016) to the 2019 was to use the US Consumer Price Index (CPI) published periodically by the US Bureau of Labor Statistics (BLS). In this approach, the ratio of the CPI for the two years of interest (i.e., CPI_{2019}/CPI_{2016}) is used to escalate the VO value from 2016 to the year 2019. A link to the CPI used is provided below.

<https://www.bls.gov/cpi/tables/detailed-reports/home.htm>

2.4 Generators Included in Report

As requested by the CAISO, the types and subtypes of units covered in this report are intended to include those types and subtypes that are representative of the generation technology installed in the Western Interconnect or those that are likely to be installed in the near future. Thus, generating plants that are one of kind or one of a few may not be represented in the report results because they do not meet the “significant market presence” criteria discussed earlier.

3 Cost Information for Generating Plants

The potential Variable Operations Cost default values for all generating plants covered by this report are shown in several tables in this Section 3. The generators have been grouped such that similar generators are listed in the same section and cost table. The information in each grouping includes:

- Name of the Generator Group
- Discussion of the generators in the group
- A brief discussion of the costs included
- A brief discussion of the key sources used to develop the VO value for generators in the group
- A table that list the Generator Types included in the Group and the VO costs in \$/MWh in 2019 dollars

Differences between Report Version 1 and 2

The following changes were made to the Version 1 report

- Additional plant types were added to Combustion Turbine and Combined Cycle group to provide for increased granularity to these subgroups. Default values are now provided for both wet and dry tower cooling towers in addition to values for with and without SCR treatment included in Version 1.
- Based upon stakeholder comments, two default values are provided for generators that have a significant market presence in California and the rest of WECC that have a significant portion of their VO cost associated with water usage or an SCR consumable (ammonia). In these cases, one default value is for generators in California and the other for the rest of WECC.
- All references to the variable operations default values used by the CAISO have been changed from VOM to VO to make it clear that the default values do not include maintenance.

3.1 Coal and Natural Gas Generators

Generators in this group include plants that are fueled by coal or natural gas in a variety of configurations. The group includes coal and natural gas-fired subcritical conventional plants.

The variable costs associated with this group of generators includes: 1) water used in water/steam cycle and other processes in the generation facility that utilize water (e.g., coal pile management), 2) chemicals associated with the plant emissions control processes and 3) waste treatment and disposal.

Chemicals that are included for this group (as appropriate to each plant) are:

- Limestone Reagent (dry FGD)
- Activated Carbon (AC) – for mercury control

- Ammonia – for NOx control
- SCR Catalyst Replacement
- Bags for Baghouse
- Other miscellaneous consumables and waste costs

Waste treatment and disposal that are included (as appropriate to each plant) are:

- Bottom Ash Disposal
- Fly Ash Disposal
- Gypsum Disposal
- AC Waste Disposal

In keeping with the aim to develop default VO values, the variable costs for this group of generator types do not include costs for obtaining NOx or SO2 allowances and do not reflect the revenue associated with the sales of waste products.

The primary sources of data used to develop these VO cost estimates included:

- Sargent and Lundy Report
- EPA Compilation of Air Pollutant Emissions Factors (AP-42) - Emissions of criteria pollutants were used to estimate NOx emissions and NOx emission control related consumables for various thermal plants.

Table 3-1: Variable Operations Costs – Coal and Natural Gas Plants (2019\$)

Plant Type	V O Cost
Coal Plant - Pulverized Coal – Subcritical	\$2.69/MWh
Oil/Gas Steam Plant – Subcritical – In CA	\$0.33/MWh

3.2 Combustion Turbine and Combined Cycles Generators

Generators in this grouping include a range of combustion turbine generator types in a both simple and combined cycle arrangements as well as aeroderivative combustion turbines. They include:

- Combined Cycle (CC) Heavy Duty Frame F – This category represents the majority of the existing CCs in WECC. The values were derived based on a 328 MW Siemens 1 x 1 x 1 SGT6-5000F Combined Cycle Power Plant.
- Combustion turbines - F Class - This category represents the majority of the frame gas turbines in WECC. The values were derived based on a 250 MW Siemens SGT6-5000F Simple Cycle Power Plant Cycle Power Plant.
- Combustion turbines (Aeroderivative) – This category represents the majority of the aeroderivative combustion turbines (LM6000 and earlier). The values were derived based on a 51 MW GE LM6000PA Simple Cycle Power Plant.

The variable costs associated with this group of generators includes: 1) water used in water/steam cycle and 2) chemicals associated with the water and plant emission's control processes, and 3) other miscellaneous consumable costs

The primary sources of data used to develop these VO cost estimates included:

- The ISO CONE Reports

Costs are provided for Combined Cycle Plants to capture plants with SCR and wet cooling while CTs are provided with SCR. The ISO intends to use the same values for both the ISO and the rest of the EIM footprint in order to create just one set of default values for each technology type. In converting costs from NYISO to the values used in this report, a multiplier of 1.21 was used for SCR catalyst and ammonia and 1.32 for water.

Table 3-2: Variable Operations Costs – Combustion Turbines and Combined Cycle Plants (\$/MWh 2019\$)

Plant Type	VO Cost
Combined Cycle CC Heavy Duty Frame F	\$0.59/MWh
Combustion Turbines – F Class	\$0.97/MWh
Combustion Turbines (Aeroderivative) LM6000	\$2.15/MWh

3.3 Nuclear

This group includes existing conventional nuclear plants with ratings of about 1100 MW.

The primary source of data used to develop these VO cost estimates is the EIA reports.

Table 3-3: Variable Operations Costs – Nuclear Plants (2019\$)

Plant Type	VO Cost
Nuclear Plant Size 1100 MWs	\$1.08/MWh

3.4 Renewable and other Generating Units with VO Costs

The plants in this group are all renewable in nature, except the Internal Combustion Engine generator which are primarily fueled by natural gas. The group includes VO costs of geothermal plants, biomass plants operating on agriculture waste, a land fill gas generation plant and an internal combustion plant. Solar thermal plants have VO costs but the ISO does not intend to propose a default value for these plants and are thus excluded from this report.

Table 3-4: Variable Operations Costs – Renewable Generators with VO (2019\$)

Plant Type	VO Cost
Geothermal Power Plant	\$1.16 MWh
Biomass Power Plant	\$1.65 MWh

Land Fill Gas	\$1.21 MWh
Internal Combustion Engine	\$1.10 MWh

The primary sources of data used to develop these VO cost estimates included:

- Geothermal H2S Abatement Report
- Sargent and Lundy
- EPA Air Pollutant Emissions Factors (AP-42)
- EIA 2016 Report
- EPA CHP Report

VO costs for these generators will vary based on type or renewable energy and technology. The following is the list of VO components for each type of generating units.

- Geothermal Power Plant – costs associated with H2S removal, and chemicals and water for the steam cycle cooling and other miscellaneous consumables and waste costs.
- Biomass Power Plant – costs associated with water for the steam cycle and for cooling system, ammonia and SCR for NOx control, ash disposal costs and other miscellaneous consumables and waste costs.
- Land Fill Gas – cost associated with NOx control (ammonia and SCR catalyst) and other miscellaneous consumables and waste costs.
- Internal Combustion Engines - cost associated with NOx control (ammonia and SCR catalyst), and other miscellaneous consumables costs.

3.5 Plants without Variable Operations Costs

There are a number of types of generation plants that do not have variable operations and maintenance cost that meet the CAISO definition of VO. That is, they don't have costs that are a function of the level of production (MWhs) that are consumables and waste related. The generation types that are in this category include:

Table 3-5: Generating Plants without Variable Operations Costs

Plant Type
Hydro
Pumped Storage
Solar PV
Wind Generators
Battery Storage Units



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