Variable Operations and Maintenance Cost Review

Revised Straw Proposal

May 4, 2020

California Independent System Operator

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1) Changes from the Straw Proposal

The CAISO appreciates the written stakeholder comments received in response to the issue paper/straw proposal and the January 6, 2020 stakeholder call. In response to this input, the CAISO has made the following proposal modifications:

Component A: Definitions

This Revised Straw Proposal proposes a few changes and clarifications to the operations and maintenance cost component definitions proposed in the Straw Proposal. The CAISO proposes to update its treatment of plant and equipment replacements by leveraging FERC's Uniform System of Accounts' definitions for *substantial betterments*, *retirement units*, and *minor items of property*. The CAISO also proposes to link labor costs with the associated operations and maintenance activity to determine whether the labor costs should be considered fixed or variable.

Component B: Refine Variable Operations Adders

In the Straw Proposal, the CAISO proposed changes to how generation technologies are grouped into default categories but did not propose updates to the adder values proposed in December 2018. In this Revised Straw Proposal, the CAISO proposes geographical updates to the Variable Operations adder values based on information of an updated report by external consultant, Nexant.

Component C: Calculate Default Maintenance Adders

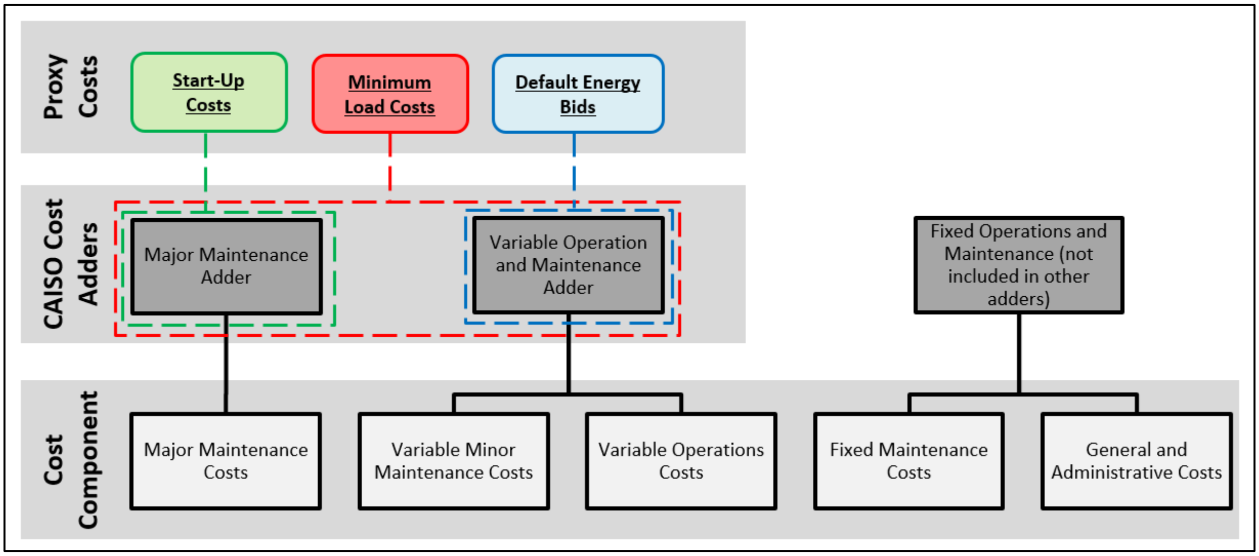
In response to a number of stakeholder comments, the CAISO proposes two options for the default maintenance adder calculation: Option 1, which relies on fewer assumptions but covers fewer resources, and Option 2, which relies on more assumptions but covers more resources. Exploring two options is intended to stimulate stakeholder participation to assess pros and cons in order to determine the best solution. By providing the detailed calculations of the two options, the CAISO shows the necessary decision points and the implications that these decisions have on the calculated default maintenance adder values. Doing so is intended to give stakeholders the opportunity to make more detailed and informed comments and recommendations on the calculated default values.

In both options, the CAISO proposes to set the default value as the minimum of interpolated major maintenance adder values that have been previously approved by the CAISO and the estimates from external sources. Doing so will provide a conservative estimate of maintenance costs and eliminate the need for the 60% scalar proposed in the Straw Proposal. An important implication of this methodology change is that the CAISO can only propose default maintenance adders for technologies that have a sufficient number of negotiated, approved MMAs.

2) Introduction

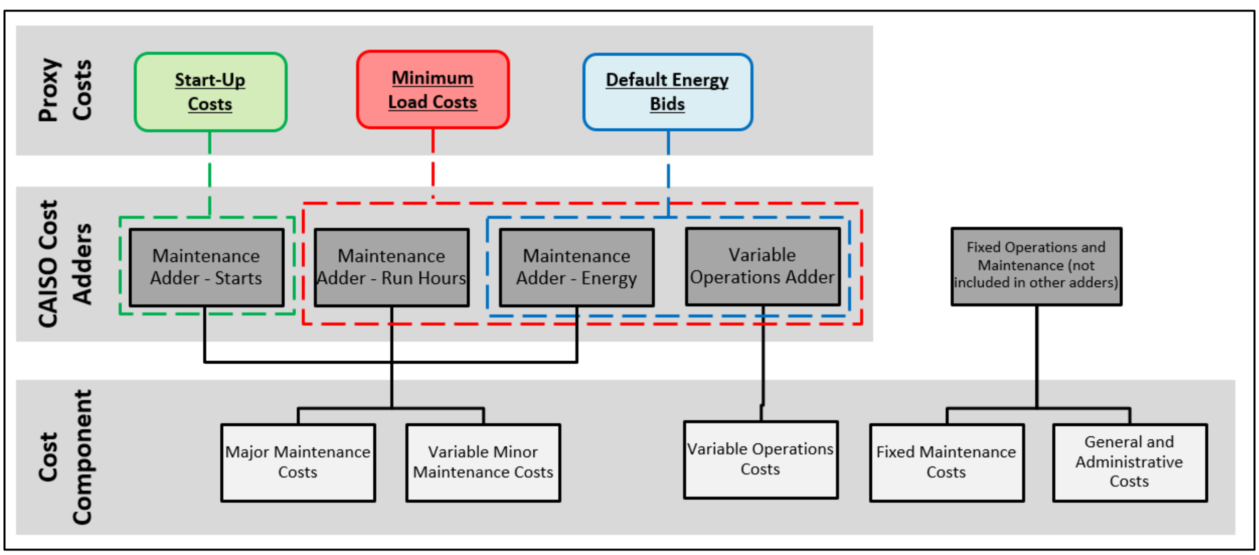
The variable operations and maintenance (VOM) adder and major maintenance adder (MMA) currently in place allow market participants to include their VOM and major maintenance costs in their bids. The CAISO includes these adders in the resource's "proxy costs", which mirror the three parts of market participants' bids into the energy markets: default energy bids (DEBs), minimum load costs, and startup costs. The VOM adder is included in DEBs 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 shows the current structure.

Figure 1 – Current Cost Recovery Framework in CAISO Markets



This initiative proposes to change the structure of how operations and maintenance (O&M) costs are estimated for use in the CAISO markets. This proposal includes three components: 1) defining the O&M cost components, including how to differentiate between fixed and variable O&M costs, 2) redefining the VOM adder as only a variable operations (VO) adder, and 3) allow market participants to bid in *all* of their variable maintenance costs through a new default maintenance adder in lieu of the current MMA. Figure 2 shows the CAISO's proposal for the updated cost structure.

Figure 2 – Proposed Cost Recovery Framework in CAISO Markets



These changes will provide a number of benefits. Creating detailed definitions will provide more clarity for the calculation of default VO and maintenance adder values and provide a clear reference during negotiations of these adders. Redefining the VOM adder as the VO adder will separate out dissimilar cost components. Finally, having conservative default maintenance adders will decrease the number of negotiations needed while also providing for more accurate costs considered in economic dispatch.

3) Stakeholder Comments

Following the posting of the Straw Proposal on December 19, 2019, the CAISO held a working group meeting on January 6, 2020 to review and further discuss all the relevant elements of the initiative. Stakeholders submitted 13 sets of comments for the Straw Proposal that the CAISO summarizes below.

Component A: Definitions

The comments submitted by stakeholders in relation to the definitions proposed in component A were largely supportive of the effort to refine the definitions of the O&M cost components.

Stakeholders' comments on definition of Variable Operations costs requested clarifications or additions to the definitions proposed. Portland General Electric (PGE) suggested that the CAISO enumerate specific items that are includable in Variable Operations costs. PGE also encouraged the CAISO to ensure the definition covers costs related to pre- and post-start activities and shutdown- and standby-related costs. Calpine requested that certain specific costs be included in the definitions, such as costs related to duct firing and steam augmentation.

The comments around the definition of Variable Maintenance costs focused on the CAISO's distinction between predictive, preventative, and corrective maintenance. Arizona Public Service (APS) and Calpine encouraged the CAISO to not disallow preventative/predictive maintenance for inclusion in Variable Maintenance while CAISO Department of Market Monitoring (DMM) cautioned against allowing all corrective maintenance. PGE suggested differentiating between preventative *monitoring* and preventative *maintenance,* with the former being a fixed cost and the latter being variable.

The CAISO also requested feedback on a specific condition that was being considered for inclusion in the definition of Variable Maintenance costs: "*[s]uch costs should not represent significant upgrades to the unit or significantly extend the life of the unit.*" Many stakeholders provided helpful comments on this condition, advocating against its inclusion and pointing instead to the FERC's definition of "substantial betterment." DMM suggested separating the discussion of replacements from the discussion of upgrades to the unit as well as encouraging a more enumerative approach regarding the definitions.

Finally, the treatment of labor costs in the definitions of Variable Operations and Variable Maintenance was questioned by stakeholders. PGE, Southern California Edison (SCE) and the DMM requested details of how regular and supplemental staff would be treated in the definitions.

Component B: Refine Variable Operations Adders

While many stakeholders withheld judgment on component B, regarding refinements to the VO adder, until updated values were presented, some stakeholders did submit helpful comments regarding the methodology used and grouping of technology types.

General methodology comments were submitted by a number of stakeholders. APS and Idaho Power Company (IPCO) IPCO encouraged the CAISO to consider adjusting the default VO adder values for certain resource-specific characteristics such as age, initial build quality, site-specific factors, or operational profiles. Middle River Power (MRP) requested clarification on how multi-stage generators (MSGs) and multi-unit resources will be treated under the new VO adder. Calpine asked the CAISO to include the methodology which will be used to escalate the values going forward. Finally, PGE, SCE, and

MRP requested that the CAISO provide the details of how the default VO adder values were derived and/or how the values stack up against the currently implement VOM values.

Stakeholders also submitted comments regarding the grouping of technology types. The most frequent comment was that the Advanced CT and Advanced CCGT groupings were inappropriate as Variable Operations costs differ significantly between advanced frame CTs (e.g. G, H, and J series CTs) and aeroderivative CTs (see Calpine, DMM, MRP comments). However, some commenters disagreed, noting that the groupings appear appropriate (see APS, CDWR, NCPA, PGE comments). Finally, APS, Calpine, and the California Public Utility Commission (CPUC) encourage the CAISO to develop VO adders for energy storage resources.

Component C: Default Maintenance Adder

The CAISO received helpful feedback from stakeholders on the proposed default maintenance adders (default MAs). A majority of the submitted comments focused on the CAISO's proposed framework for developing technology-specific default maintenance adders, specifically how to develop a robust estimation and scaling methodology.

In particular, stakeholders questioned the scaling methodology proposed by the CAISO as to whether it was appropriate to apply a scaling factor, how the scaling factor should be determined, and what explanatory variables may be considered to determine a scaling factor. Stakeholders suggested that defaults could be presented in buckets or ranges (APS, PGE), and that other explanatory variables or model types could be considered to improve the robustness of the defaults (Pacific Gas & Electric [PG&E], PGE, SCE). APS suggested that an estimated difference in run-hours and startups between the representative unit and resource specific unit, as well as considering maintenance cycles (outage to outage) or larger time periods rather than annual maintenance costs could improve the methodology.

Stakeholders requested additional clarification about the CAISO's proposed split of run-hours and starts for various technology types in Table 3 of the Straw Proposal (see CPUC, Calpine, PG&E comments). PGE and PSE noted that hydro resources may not always conform to the proposed 50/50 split due to operational restrictions and forecasting challenges. Additionally, APS provided helpful information that their advanced CT units incur costs on a 90/10 split of starts to run-hours, instead of the proposed 50/50 split. There was general concern about relying on historical dispatch and operational data to develop going-forward methodology as the typical dispatch patterns for the broader generation fleet have been evolving in recent years.

Market participants also raised concerns about how generating units smaller than the representative unit size may be at a disadvantage to recover their costs by way of the linear model and proposed scaling methodology (Northern California Power Agency [NPCA], SCE). The CPUC indicated that more information would be appropriate as to why a linear model was chosen to develop the default MA calculation and how maintenance cost allocation and capacity factors for each technology type were determined as reasonable.

Stakeholders gave feedback on the graph showing S&P Market Intelligence maintenance cost data for combined cycle units juxtaposed with the proposed default MA methodology, both scaled and unscaled (Figure 3 in the Straw Proposal). In particular, stakeholders were concerned about whether the data was an accurate representation of combined cycle resources in the CAISO/EIM resource pool, whether the data and the resulting linear regression showed adequate correlation between a unit's Pmax and annual variable maintenance costs, and whether the data sufficiently supported applying a scalar to the default MA (see APS, Calpine, NCPA, and PGE comments). APS requested that the underlying S&P data presented in the figure be released to stakeholders for further analysis.

4) Proposal

Component A: Definitions

In response to the feedback, the CAISO will update the proposal for definitions of the O&M cost components. Before formally proposing the updated definitions, the CAISO would like to clarify its intended approach to the definitions. Similar to current practice, the CAISO intends to include the principle-based definitions in the Tariff and include the interpretive guidance on these definitions in its Business Practice Manuals (BPMs). Accordingly, this section will split the discussion of the Tariff definitions and the BPM guidance. While the BPMs have a separate formal BPM change management process, the CAISO believes that it is worthwhile for this level of detail to be discussed with stakeholders during this policy development process.

The CAISO's overall goal with developing these definitions is to help in categorizing costs during negotiations and in calculating default values. The tariff definitions will focus on the defining principles of cost categorization while the BPM will be more detailed and enumerative. The overriding principle behind these definitions is that variable costs are those costs that vary with respect to production (*i.e.* MWh output, run-hours, and/or starts). Consistent with a marginal pricing approach, only variable costs can be recovered in the CAISO's spot energy markets. Stakeholders should keep this principle in mind during negotiations and when the interpretive guidance found in the BPMs doesn't fit a particular situation.

Tariff Definitions:

The CAISO proposes to add the following definitions to the Tariff.

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) of a Generating Facility, specifically excluding maintenance, allowance, and fuel costs.*

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) of the Generating Facility.*
> 2) *Such costs should reflect going-forward costs that are expected to be incurred within the lifespan of the unit.*
> 3) *Such costs should be consistent with good utility practice.*

4) *If the item is a replacement of existing plant or equipment, such costs should not effect a substantial betterment to the Generating Facility.*

Fixed Maintenance 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) of the Generating Facility.

General & Administrative Costs:

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) of the Generating Facility.

BPM Guidance Discussion:

This section will provide interpretive guidance on each of the definitions proposed and will offer specific guidance on labor costs which applies to multiple definitions.

Variable Operations Costs

As explained in the definition above, Variable Operations (VO) costs arise directly as a result of operating the Generating Facility but don't include maintenance, 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 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.

The CAISO proposes to have a variable operations adder will represent variable operations costs. Because these costs typically vary with the MWh production of a Generating Facility, the default adder is expressed as a $/MWh value. During negotiations, the CAISO will also consider VO costs that vary with the run-hours and/or start of the Generating Facility.

Variable Maintenance Costs

The definition proposed by the CAISO includes costs that are incurred when repairing, overhauling, and inspecting the Generating Facility. Costs of replacing equipment may also be included under specific circumstances which will be outlined further below. Examples include hot gas path and combustion system inspections and major overhauls. 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 due to electrical production. Further, they are costs incurred to maintain the Generating Facility, not to substantially alter it beyond its original characteristics.

Preventative, predictive, corrective, and routine maintenance costs

Resource operators have a number of approaches to maintaining their generating units. This diversity of practices includes performing corrective, preventative, predictive, or routine maintenance activities. The CAISO has included clarifying definitions of these terms in Appendix A. The CAISO expects that most variable costs would arise from corrective maintenance activities because they can easily be tied back to the production of the unit. However, predictive and preventative maintenance activities can also relate to the variable production of the unit. The latter situation may be more difficult for the market participant to demonstrate because it will require them to show that the predictive or preventative maintenance arose due to the output/run-hours/starts of the unit, rather than part of a routine maintenance cycle.

Exceptions to this general classification will always exist and, in such cases, the CAISO encourages stakeholders to consult the underlying principle: variable costs vary with respect to production. During negotiations, it may be difficult to show that predictive monitoring of equipment for damage is a variable cost but easier to show that preventative repair of a heavily used part is a variable cost. Similarly, the costs of a corrective repair of a broken equipment item will be easier to justify as variable if the damage was incurred when running the unit. Repair costs incurred due to flaws in design of a part likely didn't arise due to running the unit and thus wouldn't be considered to be variable costs.

Routine maintenance activities are those that happen at defined time or calendar intervals. Because they happen regardless of electrical production, the costs associated with routine maintenance activities are not variable. Original equipment manufacturers (OEMs) usually include maintenance guidance that define maintenance intervals. If these intervals are defined in terms of production intervals (run-hours, starts, or MWh), it will be easier to conclude that the costs are variable than if they are defined in temporal terms (e.g. perform an inspection every 5 years).

Replacements – Capital or variable costs?

During negotiations of major maintenance adders as well as through this initiative, the CAISO has encountered the question of whether the replacement of equipment, plants, etc. is a maintenance activity or a capital investment. Maintenance activities, assuming that they vary with respect to production, would be variable costs recoverable via the CAISO's short-run, spot energy market while capital investments would be long-run, capacity costs recovered elsewhere (e.g. via a Resource Adequacy contract or other capacity contract). Depending on the size, scope, and nature of the replacement, such activities could fall into either bucket, thus making this distinction important in the CAISO's definitions.

In their comments on the Straw Proposal, stakeholders indicated that the FERC Uniform System of Accounts (USofA)[1] has definitions that may be helpful in drawing this distinction. The CAISO

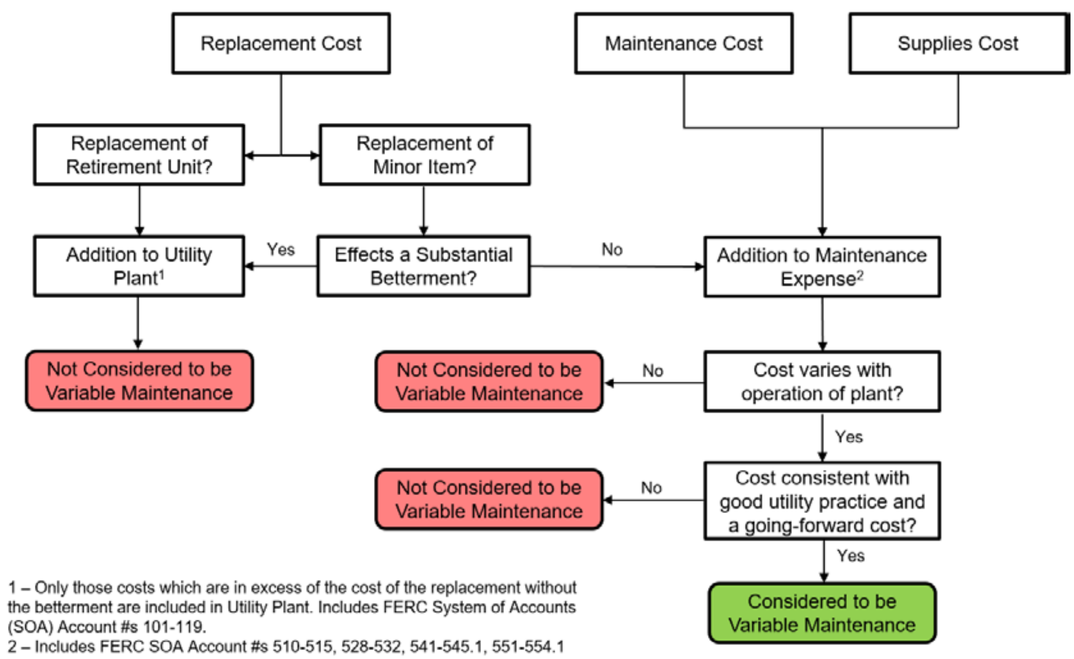
[1] https://www.ferc.gov/enforcement/acct-matts/usofa.asp

proposes to utilize a few of the FERC USofA definitions to clarify our approach towards replacements.

The FERC USofA differentiates electrical plant into two categories: 1) retirement units and 2) minor items of property. Minor items of property are the associated parts or items of which retirement units are composed[2]. Retirement units are capitalized onto the balance sheet[3] and thus would be considered a capital investment and not a variable cost. The treatment of minor items of property depends on whether the replacement "effects a substantial betterment (a primary aim of which is to make the property affected more useful, more efficient, of greater durability, or of greater capacity)." If the replacement of a minor item of property does effect a substantial betterment, some of the costs of the replacement[4] are accounted for as a *capital investment*. If not, the costs are considered to be a *maintenance expense* on the income statement during the accounting period in which they were incurred.

The CAISO proposes the following regarding the distinction above: if a replacement is considered a maintenance expense under the FERC USofA, it *may* be considered to be a variable cost by the CAISO. The other components need to be considered a variable cost by meeting conditions 1 through 3 in the definition of Variable Maintenance costs above. Figure 3 shows the CAISO's proposed decision tree to use when considering whether a replacement should be considered variable maintenance under the CAISO's definitions.

Figure 3 – Proposed Classification Decision Tree for Plant Replacements



[2] FERC USofA Definition 18

[3] FERC USofA Definition 34

[4] Only those costs which are in excess of the costs of replacement *without* the betterment are considered to be electrical plant. The remainder of the costs are considered to be a maintenance expense and thus eligible for consideration as Variable Maintenance costs by the CAISO.

Utilizing FERC's established definitions has multiple benefits. When the "substantial betterment" concept is added to the definition of Variable Maintenance, the revised Variable Maintenance definition better aligns with marginal cost pricing principles[5]. The concept is also industry-accepted and familiar to stakeholders. Finally, relying on the FERC USofA definitions gives the CAISO the ability to rely on public records about maintenance costs in this analysis and in negotiations with market participants.

The CAISO also solicited stakeholder feedback on a proposed addition to the Variable Maintenance definition regarding unit lifespan:

> *Such costs should not represent significant upgrades to the unit or significantly extend the life of the unit.*

The CAISO appreciates the feedback from stakeholders on this point and believes that the revised definition of Variable Maintenance to include FERC's USofA definitions clarifies the distinction between maintenance activities and capital investments more robustly than the initial definition above. The distinction can be complicated at times; for example, regulatory decisions related to maintaining or extending unit life may vary state-by-state and fall outside the scope of maintenance decisions made by resource owners/operators. The concept of "substantial betterment," already defined by FERC's USofA and well understood by stakeholders, is more effective at making this distinction. Therefore, the CAISO will rely on FERC's USofA definition and not include the proposed addition to the Variable Maintenance definition.

<u>General & Administrative and Fixed Maintenance Costs</u>

Because stakeholders didn't have many significant comments about these cost component definitions, this Revised Straw Proposal will not discuss them further.

<u>Labor Costs</u>

The cost of labor can be included in any of the cost components defined 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 listed above, labor costs should be considered variable if they vary with the MWh output, run-hours, or starts of the generating unit. 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

[5] The CAISO recognizes that the portion of the definition of "substantial betterment" regarding the "primary aim" of the betterment relies on a subjective assumption about the intent of a replacement. Resolving this subjectivity is beyond the scope of this initiative and the CAISO proposes to determine the primary aim of the replacement during negotiations with stakeholders.

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.

Component B: Refine Variable Operations Adders

In the Straw Proposal, the CAISO introduced the idea of the Variable Operations adder but did not propose updated values for the adder. In this Revised Straw Proposal, Nexant, an external consultant engaged by the CAISO, has proposed updated values for the VO adder. These updated values are responsive to stakeholder concerns voiced regarding the December 2018 cost report.

The updated values were determined by increasing the estimates of the cost of water used in the calculation. The values proposed in December 2018, which were derived from a number of external sources, did not use California or WECC-specific water costs. In the revised values shown below, Nexant calculated the costs of water using a 2006 California Energy Commission study: *Cost and Value of Water Use at Combined-Cycle Power Plants*. The higher costs of wet-cooled plants are reflected in the default values below. The newly proposed values are:

Table 1 – Proposed default VO Adder values

Technology Type	**VO Adder ($/MWh)**
Coal	2.69
Steam Turbines	0.33
Combined Cycle Gas Turbines (CCGTs)	0.59
Combustion Turbines (CTs)	0.97
Aeroderivative Combustion Turbines	2.15
Reciprocating Internal Combustion Engines (RICEs)	1.10
Nuclear	1.08
Biomass Power Plant	1.65
Geothermal Power Plant	1.16
Land Fill Gas	1.21

The technology types missing from the table above – Hydro, Pumped Storage, Solar, Wind – do not have Variable Operations costs which affect all or most of the resources within the respective technology type. Accordingly, the CAISO does not propose a default VO adder for these resources.

The full report drafted by Nexant is included as Appendix E of this Revised Straw Proposal. The CAISO would highlight two things regarding the information noted above.

First, the VOM (current) adder values and the VO adders (proposed) are not directly comparable. As explained in the Straw Proposal, the VOM adder includes variable operations and variable minor maintenance costs while the VO adder include only variable operations costs. The CAISO has no way to subtract out the variable minor maintenance costs from the VOM values because the CAISO does not have a formal way to differentiate minor and major maintenance costs. Indeed, this was one of the driving factors for the overall updated approach proposed in this initiative.

However, comparisons are inevitable and stakeholders have voiced their concerns that the VO adder values are lower than the VOM adder values currently in place. The CAISO recognizes these concerns and, in response, is proposing a default maintenance adder to ensure that appropriate mechanisms exist in our markets for market participants to reflect their costs in their bids. Further, the CAISO would like to highlight that there is currently a 110% (for default energy bids) and 125% (for default minimum load bids) scalar which is applied to the VO adders.

Second, the increase from the previously proposed VO adder values (in December 2018) to the newly proposed values may not be as dramatic as market participants might have expected. Water costs are only one component of the estimate of the VO adder values and thus a large adjustment in their value due to geographic considerations won't result in a proportionally large increase in the total VO adder value. The scaling methodology that Nexant applied is included in the full report that is included as Appendix E. Additionally, the CAISO has decided to use the VO adder values that include costs for selective catalyst reduction (SCR) agents for CTs, Aeroderivative CTs, and CCGTs. From a review of S&P Market Intelligence data, the CAISO has identified that a significant percentage of resources within the CAISO/EIM footprint use SCR to control their emissions and thus, including the costs in the default values is appropriate.

The CAISO would also like to address a few specific stakeholder questions:

- PG&E noted that the previously proposed VO adder values hadn't changed between the report issued in December 2018 and the ones noted in the Straw Proposal, despite the definitions having changed. The CAISO notes that, while some definitions have changed between the two documents, the definition of variable operations costs (i.e. mostly consisting of consumables) has not. Accordingly, no change in the values should be expected between the December 2018 report and the values noted in the Straw Proposal.
- Idaho Power and Puget Sound Energy noted that site- or resource-specific factors, such as zero liquid discharge requirements or production-based fees, should be considered in the development of default VO adder values. The CAISO notes that, because these factors only apply to a smaller subset of resources within a technology group, they should not be included in the default values that apply to all resources within that group. However, such costs may be eligible for inclusion in a negotiated VO adder.

Technology Groups

In the Straw Proposal, the CAISO proposed 17 technology groups. This was an increase from the 12 types currently in place but a decrease from the 30 groups proposed in the December 2018 cost report. Stakeholders were broadly supportive of the updated technology groups but some noted some potential improvements. In response to those comments, the CAISO proposes to eliminate the Advanced Combustion Turbines (CTs) group and add an Aeroderivative CTs group. This would mean that all non-aeroderivative CTs (i.e. frame CTs), would be included in the Combustion Turbines category. Similarly, the CAISO proposes to eliminate the Advanced Combined Cycle Gas Turbines (CCGT) group. The CAISO also proposes to eliminate the Solar Thermal and Integrated Coal Gasification Combined-Cycle groups due to lack of widespread representation in CAISO/EIM markets.

The CAISO considered certain technology types to be representative of the resources in the CAISO/EIM footprint. These representative technologies will serve as the basis of the CAISO's determination of default values. 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 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

Stakeholders also voiced concerns about the CAISO not proposing a VO adder value for energy storage resources in the Straw Proposal. Energy storage resources, such as lithium ion and flow batteries, are becoming increasingly important in Western energy markets and thus are worth further consideration. However, energy storage resources are currently treated as non-generating resources in the CAISO's markets and are not subject to local market power mitigation. This means that the CAISO would not use an energy storage VO adder value anywhere in the CAISO/EIM markets, as the markets are currently designed. Further, because of the nascent nature of the technology and the very recent deployment *en masse* of grid-scale storage resources, the CAISO's and market participants' experience with such resources is limited. This lack of experience means that defining what costs are "variable" is incredibly challenging, particularly due to the ability of such resources to both discharge and charge. Based on these reasons, the CAISO will not propose a default VO adder value for energy storage resources under this initiative. The CAISO will consider energy storage and other developing technologies in its triannual review cycle discussed below.

Inflation Methodology

In the cost report issued in December 2018, Nexant discusses how they adjusted the values found in external source documentation to the values proposed in the cost report for inflation by using the consumer price index published by the US Bureau of Labor Statistics. The CAISO agrees that this approach is appropriate for the purpose of adjusting the values from external sources to be comparable to the current values being proposed.

However, the CAISO would like to clarify that it is not proposing a methodology to adjust the default VO values for inflation to be applied in future years. In the past, the CAISO agreed to review the VOM adder values once every three years to see if an update was needed. The CAISO still expects to perform this review but does not think that committing to a methodology whereby an inflation adjustment is blindly applied to the default VO adder values is appropriate. Such an across-the-board application of a time-specific scalar might not catch differences in the resource mix, individual commodity price changes, etc. During the triannual reviews, the CAISO will consider whether inflation should be considered along with other factors that may affect the VO costs.

Component C: Calculate Default Maintenance Adders

This section will outline two proposed options for the calculation of the default MAs and provide further analysis supporting the resulting values and methodology. While the entire proposed methodology will be discussed, the CAISO's primary focus will be on three broad areas: 1) the source of the data used as estimates of the annual maintenance costs, 2) the calculations performed to translate the external source data into default maintenance adders, and 3) the methodology for scaling the default maintenance adders to calculate a resource-specific maintenance adder.

The CAISO proposes two options for the default MA calculation: Option 1, which relies on fewer assumptions but covers fewer resources and thus less points in the data sample, and Option 2, which relies on more assumptions but covers more resources. Because the CAISO will perform the calculation on a technology-specific level and needs to be consistent across all technology types, these two options are mutually exclusive. Accordingly, the CAISO is soliciting comments on the merits of each option.

In both options, the CAISO proposes to cross-validate the default value calculated from the external sources against interpolated major maintenance adder values that have been approved by the CAISO. Doing so will provide a conservative estimate of maintenance costs and also eliminate the need for the 60% scalar proposed in the Straw Proposal. An important implication of this methodology change is that the CAISO can only propose default MAs for technologies that have a sufficient number of MMAs (see how the ISO made this determination in Step 4 below). In other words, the CAISO cannot propose default MA values for some technology types because the CAISO is unable to cross-validate the external estimates against Variable Maintenance costs that have been verified during MMA negotiations.

The two options differ on the number of external sources used, the level of conversions necessary to translate the external source data into a $/start or $/run-hour format, and the number of resources to which they would apply. The CAISO believes that the ultimate decision on which option to pursue should be informed by the level of assumptions and approximations that are reasonable, balanced by the coverage provided by the resulting default MAs.

An example of the tension between these competing goals is the conversion of a $/MWh value to a $/run-hour value. In doing so, the CAISO introduces assumptions into the calculation. This conversion requires an assumption about the capacity factor. If the CAISO uses a capacity factor different than the one used implicitly in the external source, the resulting default MA value may be incorrect. However, in the case of Hydro resources, not performing this conversion keeps the CAISO from being able to cross-validate the external estimates against verified MMA values, and thus from proposing a default value for Hydro resources.

Utilizing fewer assumptions, especially regarding unit conversions, results in the CAISO being able to propose default MA values for fewer technology types. In Option 1, the option with fewer assumptions, the calculation results in default MAs for three technology types that represent or "cover" only 37% of resources with variable maintenance costs[6]. On the other hand, Option 2, which has more assumptions and thus more uncertainty, proposes default MA values for four technology types, doubling the amount of resources covered to 75%.

The CAISO will use this section to outline the two different options and walk through the steps to calculate the default MAs under both options. The body of the paper will focus on where the calculations differ to draw stakeholders' attention to key decision points and thus may skip certain details. The full calculations are included as an attachment to this paper and should be used to supplement the discussion in this section. Table 2 has an overview of the two different options while Table 11 at the end of this section has a summary of the advantages and disadvantages of each option.

Table 2 - Overview of the two default MAs options:

	Option 1	*Option 2*
Inputs		
Number of external sources used per technology	Single source	Multiple sources
Conversions		
Conversions of VOM to variable maintenance allowed?	No	Yes
Conversions between adder types ($/MWh, $/run-hour, $/start) allowed?	No	Yes
Outputs		
# of technology types covered	3	4
Coverage of proposed DMAs[6]	37% of resources	75% of resources

Both of the proposals utilize a similar methodology in their calculation:

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 interpolated major maintenance adder values to determine a default maintenance adder
5) Using the default maintenance adder, calculate a unit-specific adder

Stakeholders will find that decisions made in earlier steps are driven by requirements from later steps. For example, the need to cross-validate the external sources against existing MMA values (Step 3) drives the need to determine which adder type is most appropriate (Step 2). During an initial read of the detailed steps below, some decisions or calculations may appear to be arbitrary or arcane. However, the

[6] 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).

CAISO believes that each step is integral to arrive at a resource-specific MA. Because of the interdependency of each step, the CAISO encourages the reader to have the ultimate goal – the calculation of a default maintenance adder – in mind when considering each step.

Step 1: Estimate variable maintenance costs using external sources

The proposed options utilize external sources to estimate variable maintenance costs. Option 1 utilizes a single source per technology type, while Option 2 utilizes multiple sources per technology type.

Table 3 – External sources used in the default value calculations

	Option 1	*Option 2*
Technology Type	**External Source**	**External Source**
Combined Cycle Gas Turbines (CCGTs)	NYISO (2016)	- NYISO (2016) - APS (2017) - PSE (2018) - EIA (2020)
Combustion Turbines (CTs)	NYISO (2016)	- NYISO (2016) - APS (2017) - Pacificorp [PAC] (2019) - PSE (2018) - EIA (2020)
Aeroderivative Combustion Turbines	NYISO (2010)	- NYISO (2010) - APS (2017) - PAC (2019) - EIA (2020)
Hydro	N/A	- EPA (2016) - EIA (2020)

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

- **Definitional appropriateness**: The CAISO sought out sources that have definitions of variable maintenance costs similar to those proposed above. Sources that specifically mention that their estimates include major maintenance costs, the largest component of variable maintenance costs, were preferred over those that did not. On this basis, the NYISO reports were found to be the most consistent with the CAISO's proposed definitions and thus were considered the primary source in Option 1 and one of the sources in Option 2. The other sources usually did not specifically enumerate their definitions of VOM costs. In these cases, to estimate only variable maintenance costs, the CAISO subtracts out the VO adders values, proposed in component B above, from the VOM value provided in the reports to arrive at variable maintenance costs. The final step has a potentially large impact on the final calculation of the default MA if the implied VO cost estimate in the source documentation differs from the CAISO's estimate of VO 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 translated the labor component to WECC-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 used 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 used estimates from external sources if the turbine technology was representative of the resources in the CAISO/EIM footprint. This is discussed further in component B above.

- **Credibility:** The CAISO chose sources that are reputable, unbiased, and, ideally, from equipment manufacturers or operators. The CAISO preferred sources that were filed with regulatory bodies, such as public utility commissions, over those released for informational purposes only.

Differences between Option 1 and 2:

As Table 3 shows above, Option 2 has more sources of cost data than Option 1 does. The decision to base the calculations on multiple, diverse sources (as exemplified by Option 2) versus a single, solid source (as exemplified by Option 1) should be informed by a few factors:

> Multiple sources: Using multiple sources allows for a diversity of estimates, which will account for differences in definitions between sources and limit the impact of any outliers. Further, this will allow the CAISO to update the default MA values more robustly in the future, rather than relying on a single source that may not be updated frequently. Also, the use of multiple sources diminishes the importance of the assumptions made within any individual source. The final result of the calculation is thus less sensitive to an inappropriate assumption or inconsistent definition used in the calculations. Finally, the CAISO can choose sources that represent resources actually in the CAISO markets and thus reflect market participants' estimates of costs.
>
> However, not all of these sources are expressed in a way that fits the CAISO's exact needs. The knowledge gained over years of MMA negotiations is that major maintenance costs are typically analyzed in $/cycle terms (e.g. $2M per maintenance cycle for a hot gas path inspection, where a cycle is 25,000 hours). This is, however, only for major maintenance costs; variable minor maintenance costs are likely not expressed in a $/cycle format and may instead be presented in a $/MWh or $/year basis.
>
> Single source: A single source, such as the NYISO estimates used in Option 1, allows for the cleanest, easiest to explain, and least-resistance path to arriving at a $/run-hour or $/start value. Because these values can be derived directly from the report with minimal assumptions, the CAISO has the most assurance that the resulting default MAs are consistent with our definitions. A single source, however, may present a myopic picture of maintenance costs and be overly sensitive to the assumptions made by the author.

Unit conversion in external sources

Before presenting the values estimated from the external sources, the CAISO would like to call attention to the importance of the units of measurement (UOMs) of the external cost estimates on the subsequent steps of the calculation and, ultimately, the choice between Option 1 and 2. The cost estimates found in the external sources come in multiple different UOMs such costs per maintenance cycle ($/cycle) and variable operations and maintenance costs per unit of energy ($/MWh). Ultimately, the CAISO needs the variable maintenance costs to be expressed in a UOM that aligns with the parts of the three-part bid made into the CAISO energy markets: $/MWh, $/run-hour, or $/start.

When an external source is in a different UOM than one of those three formats, the CAISO needs to convert the units using a conversion factor. In some cases, the conversion between UOMs is simple and relies on a solid assumption. For example, the NYISO report contains cost estimates in a $/cycle format with a readily available conversion factor, likely from the OEM, of 48,000 run-hours/cycle. With that information, the conversion from the $/cycle format to a $/run-hour format is simple and does not involve a major assumption.

To make the NYISO values comparable across technology types, the CAISO divides the $/cycle values by the max operating capacity, or Pmax, of the resources derived from the source documentation to arrive at a $/cycle per MW value. For example, for CCGTs, the NYISO's estimate of variable maintenance costs per cycle is $40.3M/cycle or $839/run-hour. With the Pmax of the generating resource of 328 MW, the $/cycle per MW value is $123,203 or $2.57/run-hour per MW. The relative simplicity of this conversion is one of the largest advantages of Option 1.

Option 2 relies on multiple sources that are in different formats from each other. APS, Pacificorp, and PSE express their VOM estimates in a $/MWh format instead of in a $/cycle format. To make these values consistent with each other, the CAISO converts each into $/year values[7]. To convert the NYISO estimates to $/year units, the CAISO needs a conversion factor of starts per year or run-hours per year. This information isn't readily available in the NYISO report, so the CAISO calculates this ratio on a technology-specific level based on CAISO/EIM operating data.

For example, for CCGTs, the NYISO's estimate of variable maintenance costs per cycle is $40.3M/cycle. The CAISO calculates an average of run-hours per year for CCGTs based on its internal operating data to be 4,306 run-hours/year. With the given conversion factor of 48,000 run-hours/year and the assumed conversion factor of 4,306 run-hours/year, the CAISO arrives at an estimate of $2.1M/year for CCGTs. To make the NYISO values comparable both across technology types and to the other sources, the CAISO also divides the $/year values by Pmax. For example, the Pmax of the CCGT resources in the NYISO report is an average of 328MW making their $/year per MW variable maintenance cost estimate equal $11,053.

This CAISO highlights this detailed and perhaps arcane set of calculations because of its importance on the end result of the default MA. For example, if the assumed run-hours per year conversion factor is halved to 2,153 run-hours/year, the resulting default MA would be halved. When making these conversions, the CAISO is implicitly assuming that the operating profile of generating resources in the CAISO/EIM footprint is the same as those in NYISO. This is a potentially large leap because of the difference in generation mix between NYISO and the CAISO/EIM, thus introducing uncertainty into the calculation of default MAs under Option 2. Option 2 partially addresses this uncertainty in two ways: 1) it uses multiple sources which diminishes the importance of the underlying assumptions from each individual source, and 2) it cross-validates the estimates against negotiated MMAs to ensure the conservativeness of the estimates.

Estimated variable maintenance costs by technology type

Using the external sources and conversion factors discussed above, the CAISO arrives at the values below. Note that Option 1 and Option 2 are presented in different UOMs. The UOMs for Option 2 are $/year per MW to make the values comparable across the different external sources.

[7] Note: this does not reflect the CAISO's belief that maintenance costs are incurred on an annual basis. The CAISO understands that most major maintenance costs are incurred on longer maintenance cycles. The $/year format was used because it involves the least amount of unit conversions for most of the sources.

Table 4– Option 1 Variable Maintenance Costs ($/cycle per MW)

Technology Type	VM Costs
CCGTs	123,203
CTs	125,118
Aeroderivative CTs	266,407

Table 5 – Option 2 Variable Maintenance Costs ($/year per MW)

	NYISO	*EPA*	*APS*	*PAC*	*PSE*	*EIA*
Technology Type	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**
CCGTs	11,053		6,626		3,804	5,824
CTs	3,324		1,235	6,178	2,102	4,168
Aeroderivative CTs	3,657		201	3,750		1,284
Hydro		8,321				4,021

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 UOMs, 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[8], the CAISO must determine whether a default adder type for each technology. The need to make this determination is driven by the need for the external estimate values to be expressed in only one format in order to cross-validate them against existing MMAs. 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 MA with the CAISO.

The CAISO's proposals were driven by information in the external source documentation and experience gained while negotiating MMAs. The proposals are as follows:

- **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. This assumption is different from the 2010 NYISO report that assumes that the cycle will be driven by starts[9]. While the 2016 NYISO report assumes a ratio of run-hours/starts of 20 (based on 48,000 run-hours and 2,400 starts per cycle), the CAISO/EIM operating data indicates that ratio is closer to 34 run-hours/start. This would mean that the average CCGT in the CAISO/EIM would reach 48,000 hours before 2,400 starts.
- **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

[8] 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.
[9] See page 31 of the 2010 NYISO report.

the Straw Proposal, APS noted that approximately 90% of variable maintenance costs of its 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%). Also, the 2010 NYISO report indicates that maintenance cycles for aeroderivative CTs are driven by run-hours[9].
- **Hydro (Option 2 only):** 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 however, the CAISO believes that Hydro resources are more likely to incur costs based on run-hours, rather than starts.

These proposals represent a shift from the Straw Proposal where a 50/50 split between run-hours and starts was proposed. The CAISO recognizes that the default adders do not perfectly capture the way that generating resources incur their costs; for example, CCGTs incur costs based on starts as wells as run-hours. Market participants have different asset management strategies that favor certain allocations and thus no proposal will fit every participant's case. The CAISO will discuss negotiations in greater detail in the *Implementation of new default values* section below.

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

As discussed above, the external cost estimates are often not presented in the adder type format that is proposed in Step 2. For Option 1, the values were presented in $/cycle format while in Option 2, the CAISO converted the values to a $/year per MW format. In this step, the CAISO converts these different formats to the appropriate adder type ($/start or $/run-hour).

For Option 1, the CAISO performs a simple conversion using the starts/cycle or run-hours/cycle conversion factors found in the source documentation. The starts/cycle and run-hours/cycle conversion factors are similar to those that the CAISO has seen during MMA negotiations and appear reasonable. As mentioned above, the simplicity of this conversion is a key benefit of Option 1.

For Option 2, the conversions needed are slightly more complicated and involve operating data (starts/year and run-hours/year) from the CAISO and EIM areas. As noted above, using CAISO/EIM-derived operating data introduces some additional assumptions to the calculation of default MAs. The core assumption introduced is that the operating data that the CAISO uses as a conversion factor is the same as the operating data used in the source documentation[10]. For example, the CAISO estimates that run-hours/year for CCGTs is 4,306 run-hours/year. This 4,306 run-hours/year could likely differ from the source documentation's estimates and thus could result in different default MA.

Also, in Option 2, the CAISO calculates a weighted average for the resulting $/run-hour per MW and $/start per MW values across the multiple external sources. This approach partially mitigates the impact of the assumptions made about operating data. The CAISO recognizes that the sources that involve the fewest assumed conversion factors and have the most explicitly stated definitions are more reliable for the purposes of calculating a default MA. Because of this, we select a "primary" source that is weighted

[10] The CAISO could potentially mitigate the impact of this by using balancing area-specific operating data instead of operating data aggregated at the CAISO/EIM level. However, the CAISO is excluding this more detailed data to avoid confidentiality concerns. The CAISO will explore the use of balancing-area specific data in future proposals.

50% with the remaining sources being weighted 50% combined. For gas and hydro resources, the CAISO selected the NYISO and EPA reports to be "primary" sources, respectively.

Table 6 – Option 1 External Estimate Variable Maintenance Costs

Technology Type	VM Costs	Units
CCGTs	2.57	$/run-hour per MW
CTs	52.13	$/start per MW
Aeroderivative CTs	5.33	$/ run-hour per MW

Table 7– Option 2 External Estimate Variable Maintenance Costs

	*NYISO**	*EPA**	*APS*	*PAC*	*PSE*	*EIA*	*Wtd. Avg.*	
Technology Type	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**VM Costs**	**Units**
CCGTs	2.57		1.54		0.88	1.35	1.91	$/run-hour per MW
CTs	52.13		19.36	96.88	32.96	65.36	52.89	$/start per MW
Aeroderivative CTs	5.33		0.29	5.46		1.87	3.94	$/ run-hour per MW
Hydro		1.51				0.73	1.12	$/ run-hour per MW

* - Primary source. Estimates from this source were weighted 50% of the weighted average for the technology.

Step 4: Cross-validate the estimate from external sources against interpolated major maintenance adder values to determine a default maintenance adder

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. Ensuring our estimates are conservative is important for a few reasons. 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 our estimates. However, the concept of default MA is being introduced for the purpose of lowering the administrative burden of processing many resource-specific negotiations for both market participants and the CAISO.

To balance these two competing goals, the CAISO proposes to limit the proposed maintenance adder values to an interpolation of currently approved MMA values. For technology types in which the external sources exceed the interpolation of the MMA values, the CAISO will use the interpolation of the MMA values. The CAISO created the interpolation of MMA values by performing an ordinary least squares linear regression[11] on the existing MMA values for each technology type. An interpolation was created for each technology type with a sufficient number of MMAs[12]. For each technology type, if the regression coefficient exceeds the average $/run-hour per MW or $/start per MW value calculated from the external sources, the CAISO uses the regression coefficient as the default MA instead.

This approach has two important implications. The first is that the CAISO can only calculate robust default MAs for three technology types under Option 1 and four technology types under Option 2. Only these technology types had 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 interpolated MMA values. Doing so may result in releasing confidential maintenance cost data that is covered by non-disclosure agreements. The CAISO recognizes that this is not the optimal solution but it is one driven by confidentiality requirements.

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

Default Maintenance Adder = min (External Estimate VM Costs, Interpolated MMA Value)

Table 8 – Option 1 Proposed default maintenance adder

Technology Type	External Estimate VM Costs	Interpolated MMA Values	Default MA	Units
CCGTs	2.57	1.69	1.69	$/run-hour per MW
CTs	52.13		52.13	$/start per MW
Aeroderivative CTs	5.33		5.33	$/ run-hour per MW

Table 9 – Option 2 Proposed default maintenance adder

Technology Type	External Estimate VM Costs	Interpolated MMA Values	Default MA	Units
CCGTs	1.91	1.69	1.69	$/run-hour per MW
CTs	52.89		52.89	$/start per MW
Aeroderivative CTs	3.94		3.94	$/ run-hour per MW
Hydro	1.12	0.36	0.36	$/ run-hour per MW

Step 5: Using the default maintenance adder, calculate a resource-specific adder

As noted above, the details of this step were among the most controversial of the Straw Proposal. In response to the comments received, the CAISO proposes to remove the 60% scalar that was applied to

[11] For more discussion on the statistical approach taken, please see the discussion on scaling Appendix B.
[12] The ISO determined that a sufficient number of MMAs was that the technology type had to have at least 20 resources with negotiated MMAs based on actual costs, rather than PPAs or LTSAs. Further, the resulting regression coefficient has to pass a t-test using an alpha value of 0.01.

the default MA to arrive at a resource-specific maintenance adder. However, the CAISO does not propose to update the use of the capacity of the resource (i.e., it's Pmax) in scaling default MA. The resulting unit-specific adder calculation is proposed as follows:

*Unit-specific MA = Default MA * Resource's Pmax*

The 60% scalar that was proposed in the Straw Proposal was intended to ensure that the calculation of a resource-specific maintenance adder resulted in a sufficiently conservative estimate. This goal has now been achieved by limiting our estimate to interpolated MMA values, as discussed in Step 4.

The CAISO includes its supporting analysis for the scaling methodology in Appendix B. The analysis is intended to: 1) support the claim that using Pmax has a statistically significant relationship with maintenance costs and, 2) explain that different scaling methodologies are either worse or statistically indistinguishable from using Pmax as the only explanatory variable. Taken together, these assertions support the CAISO's proposal to maintain the use of Pmax in the calculation of the resource-specific maintenance adder.

Implementation of new default values

Stakeholders submitted questions about the status of their existing negotiated MMA and VOM values upon implementation of this proposal. The CAISO proposes the following related to these values:

Table 10 – Proposed implementation approaches

Situation	Proposal
Resources with no negotiated MMA	Upon implementation, these resources will be assigned a resource-specific maintenance adder based on the calculation described above. Resources that do not fit into the technology groups above can negotiate maintenance adders.
Resources with a negotiated MMA	Upon implementation, these resources will be allowed to keep their existing MMA values. However, as noted in Attachment L.6 of the BPM for Market Instruments, if a circumstance arises that would trigger a review or renegotiation of an MMA, negotiations would then take place under the new cost definitions. If the scheduling coordinator would prefer to use the resource-specific maintenance adder, they can contact the CAISO to switch over to the new resource-specific maintenance adder.
Resources with a default VOM adder	Upon implementation, these resources will be assigned to their respective default VO adder value based on the calculation described above.
Resources with a negotiated VOM adder	Upon implementation, the CAISO proposes to set these resources' VOM adders to the new default VO adder values. The CAISO will not allow resources to keep their negotiated VOM values because the old VOM adder has both the VO and variable minor maintenance cost components. The variable minor maintenance cost component will now be represented in the resource-specific maintenance adder value resulting in double-counting between the two adders.

	The only exception to this is if the existing negotiated VOM value is below the new negotiated default VO adder. If this the case, the market participant can keep the negotiated VOM value as their new VO adder.

The items above supersede the Straw Proposal's discussion replacing negotiated values that were accepted after 1/1/2020 with default values.

Negotiations of adders after implementation

In the Straw Proposal, the CAISO proposed to allow market participants to negotiate their VO and resource-specific maintenance adders if the default values proposed are insufficient. The CAISO proposes to change this for both Option 1 and Option 2, with Option 1 having slightly more flexibility than Option 2.

For Option 1, the only incremental change that the CAISO proposes in the Revised Straw Proposal is that the CAISO proposes to change how the components of the maintenance adder can be negotiated. Market participants will have two options for negotiations for CT and CCGT resources: full negotiations (i.e. negotiating the final adder value) or streamlined negotiations where they can negotiate only the allocation percentages between $/run-hour and $/start adders. The latter option will allow market participants who believe that the default adder type is inadequate to request a change between adder types. This results in shorter negotiations than full negotiations, easing some administrative burden. Only CT and CCGT resources can utilize this streamlined negotiation process because, in the relevant external source documentation, these are the only technology types with clearly defined $/cycle data and both run-hour/cycle and start/cycle conversion factors. The CAISO no longer proposes that the other components (e.g. the estimated annual variable maintenance costs) be negotiable individually.

For Option 2, the CAISO does not propose any partial or streamlined negotiations. This is an implication of averaging multiple sources together: an integral input into the negotiations, $/cycle data, is missing under Option 2.

Timeline considerations

In the Straw Proposal, 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 MA applications and questions. This 15-day period is intended to provide market participants with a timely response to their MMA application. The CAISO now formally proposes 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 adders after they have been accepted. The CAISO proposes to extend this to a 30 *business* day period.

Summary of advantages and disadvantages of options 1 and 2

Table 11 – Summary of advantages and disadvantages of options 1 and 2:

Option 1	*Option 2*
Inputs	
Advantages: - Clear connection between source documentation and proposed default MA Disadvantages: - Single source may present a limited estimate of costs - May be difficult to update inputs in the future if external estimate source changes/is unavailable	Advantages: - Multiple sources incorporate a variety of estimates - Uses estimates from CAISO and EIM area - Allows for future updates of inputs as new data become available Disadvantages: - In some cases, CAISO needs to subtract out VO costs from VOM number, introducing uncertainty
Conversions/Calculations	
Advantages: - Few conversions necessary to convert the external source estimates to default MA values Disadvantages: - None	Advantages: - Averaging of sources diminishes the importance of individual estimates made in source documentation Disadvantages: - Unit conversions using CAISO/EIM operating data introduces uncertainty into calculation
Outputs	
Advantages: - Allows for some flexibility for streamlined negotiations for CT and CCGT resources Disadvantages: - Only three technologies, representing 37% of resources, are covered	Advantages: - Proposed default MAs covers more technologies and resources: four technologies, representing 74% of resources Disadvantages: - No streamlined negotiations are possible

5) 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 dayahead 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.

6) Stakeholder Engagement

The schedule for stakeholder engagement is detailed below in Table 12. The CAISO will discuss this Revised Straw Proposal paper with stakeholders during a call on May 11, 2020 at 01:00PM PT. Stakeholders can submit written comments regarding this Straw Proposal paper by May 25, 2020 to initiativecomments@caiso.com.

Stakeholder Timeline

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

Table 12 – 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 10, 2020	Post Draft Final Proposal
August 17, 2020	Hold stakeholder call on Draft Final Proposal
August 31, 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
Independent Release 2021 *or* Spring 2021 Release	Go-Live

7) References

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Appendices

Appendix A: Clarifying Definitions

This section is intended to augment the terms and definitions discussed in the proposals above.

Corrective Maintenance: Corrective maintenance is maintenance performed after-the-fact when a part fails or equipment malfunctions and is performed on a reactive, as-needed basis. It thus may be considered as a variable maintenance cost.

Predictive Maintenance: Predictive maintenance is routine maintenance performed to determine the actual condition of equipment, automatically (e.g. via sensors) or by physical inspection of specific parts, to give an estimated window for when maintenance needs to be performed before malfunction or failure.

Preventative Maintenance: Preventative maintenance encompasses the maintenance activities that attempt to identify a malfunction or failure before it occurs via regular maintenance and inspection. This type of maintenance will typically occur on a regular schedule, regardless of the activity of the Generating Facility.

Appendix B: Calculations Supporting Scaling Methodology

The analysis uses maintenance cost data gathered from the S&P Market Intelligence platform. The maintenance cost data is derived from FERC Form 1 filings from resources within WECC. The maintenance cost data is consolidated at the plant level, in contrast to the analysis in the Straw Proposal that used individual turbine-level data. It has been averaged over the calendar years 2014 through 2018 in order to account for year over year fluctuations (except where noted). Finally, the annual maintenance cost data has been divided by a constant value (the CAISO's estimate of run-hours per year) to make the cost data comparable to the major maintenance adder values. Doing so does not affect the statistical conclusions reached about the data.

Figure 4 is a visualization of several potential scaling methodologies. It shows the relationship between Pmax and maintenance costs from the S&P data. The black line, which is a representation of the CAISO's proposed scaling methodology, is an OLS regression of this relationship with an intercept of 0. The red and blue lines represent other potential relationships between maintenance costs and Pmax using the results of linear regressions using square root and natural logarithm transformations of Pmax, respectively. The green line is the arithmetic mean of the maintenance costs.

Figure 4 - Comparison of Maintenance Costs and Pmax of Resources[13] (CCGTs)

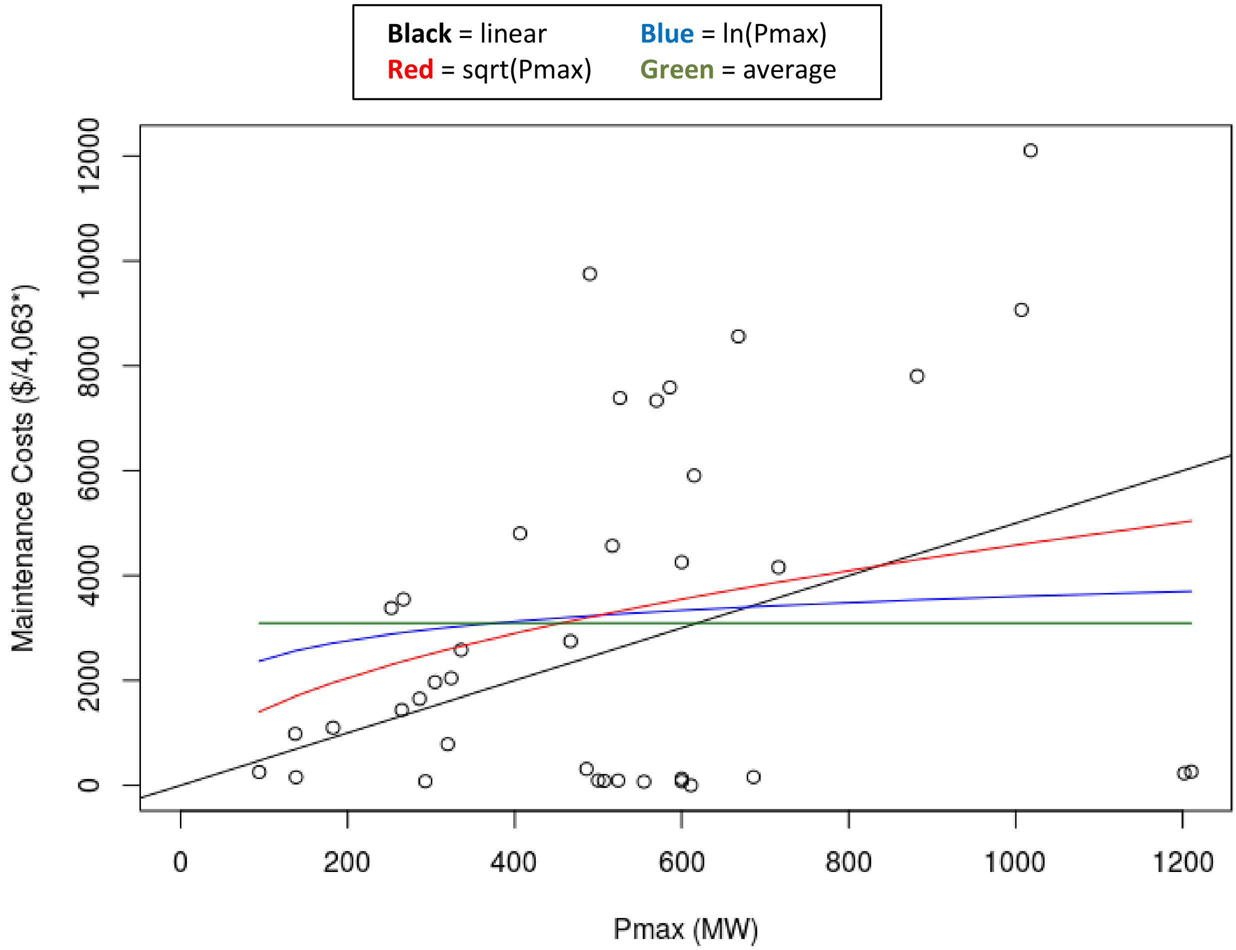

Table 10 shows the results of the regressions represented above as well as one additional model. The additional model uses both Pmax and the age of the unit as explanatory variables. The CAISO also performed an analysis on the panel data (i.e. annual maintenance costs were not averaged over the 5-year period) using both a plant and a year fixed effects model. These results did not improve the model and were excluded for length and clarity.

Table 13 – Regression Results (CCGTs)

Scaling Approach	T-statistic	Adjusted R^2
1) Linear (Pmax only)	6.229 ***	0.4987
2) Linear (Pmax and Age)	Pmax = 3.301^ Age = 1.004^	0.4988
3) Logarithmic	5.961 ***	0.4761
3) Square root	6.371 ***	0.5102

*** - *Statistically significant at p < 0.001*
^ - *p > 0.05*

[13] Source: S&P Global Market Intelligence

Several conclusions can be drawn from the regression results. First, the results show that there is a statistically significant correlation between Pmax and maintenance costs. Specifically, a t-statistic of 6.229 indicates a $p<0.001$ (*i.e.* the probability of the proposed relationship being only due to random fluctuations is very low). While not necessary for statistical conclusions, the adjusted R^2 of ~0.5 indicates that almost half of the fluctuations in maintenance costs are explained by the size of the unit. Autocorrelation is not an issue because the CAISO is treating this data as cross-sectional. These results also hold true for the other technology types. This is evidence that using Pmax to scale the resource-specific maintenance adder is appropriate. Second, models that change the functional form of the model are statistically indistinguishable from each other. This provides evidence that using our proposed simple linear model is as appropriate as using a more complicated one. Finally, including age as an explanatory variable actually decreases the explanatory value of the model, evidencing that a simpler model using only Pmax is appropriate.

The CAISO considered the inclusion of other explanatory variables but ruled them out for a few reasons. Explanatory variables such as efficiency were not used because of the lack of available data. Run-hours and starts were also excluded as explanatory variables in these models. The first reason why the CAISO did not use them was a lack of data in the source documentation; typically, only capacity factor was provided in the source documentation. The second and more important reason is that this would be conceptually inappropriate. Run-hours and starts are drivers of maintenance costs; indeed this is a core tenet of this initiative. However, the amount that resources are compensated for run-hours and starts is already based on how long the resources run and are started. A resource can already bid in its maintenance costs in their minimum load and start bids. Calculating their $/run-hour or $/start maintenance costs based on their run-hours or starts would be circular. Said differently, if resources which ran more hours than the reference unit received a higher $/run-hour adder, these resources would receive both higher payments due to a higher adder and due to having more run-hours over which they can apply the adder.

Notes on S&P data used:

The CAISO received a number of comments on the Straw Proposal about use of S&P data to support our scaling methodology. This section is intended to address these questions and anticipate future questions about the data based on the updated methodology above. Regarding the S&P data presented in the initial Straw Proposal (Figure 3), the CAISO would like to reiterate that the chart was intended to provide a representative example of the proposed scaling methodology to show that, using combined cycle gas turbine unit data from S&P, a 60% scalar was well aligned with the linear regression of the dataset. This dataset was not used to derive the entire default maintenance adder methodology proposed in the initial Straw Proposal but rather to show support for a scalar that would result in conservative estimates of resource-specific maintenance costs.

The above data is intended only to analyze the relationship between Pmax and maintenance costs. The CAISO is not intending to come up with an expected $/run-hour adder based on the FERC reported maintenance data and regression analysis presented above. Using the data discussed above to propose an adder value would be inappropriate because the maintenance costs reported to FERC don't align with our proposed definitions above. Specifically, the data above includes both Fixed and Variable Maintenance costs meaning our estimates of Variable Maintenance costs would be incorrect per our proposed definitions. However, the CAISO does not believe that, because of this fact, using the FERC reported maintenance data to support our claims about linear scaling is inappropriate. For our results not to hold, Fixed and Variable Maintenance costs would have to be negatively correlated as Pmax increases which the CAISO believes to be a less likely case than Fixed and Variable Maintenance costs being positively correlated as Pmax increases.

Finally, some market participants requested that the data used in the analysis to be published externally. The CAISO pulled this data from the S&P Market Intelligence platform for which the CAISO pays a subscription fee. As such, the CAISO does not think it is appropriate to publish this data externally. However, the CAISO's use of only FERC-reported maintenance costs derived from FERC Form 1s allows market participants to recreate the dataset should they wish to perform their own analysis.

Appendix C: Example Calculation

The following example outlines the methodology for calculating a resource-specific maintenance adder for an Aeroderivative CT unit under both Option 1 and Option 2. For multi-stage generators, this same calculation would be performed for each configuration, based on the Pmax of each configuration.

Option 1 Example

Table 14 – Option 1 Example

Parameter	***Value***
Technology Type	Aeroderivative CT
Pmax of resource/configuration (MW)	50
Proposed default maintenance adder ($/run-hour per MW) *See Table 8*	5.33

Resource-specific maintenance adder = default maintenance adder * Pmax of resource

= $5.33 * 50

= $266.50/run-hour

Option 2 Example

Table 15 – Option 2 Example

Parameter	***Value***
Technology Type	Aeroderivative CT
Pmax of resource/configuration (MW)	50
Proposed default maintenance adder ($/run-hour per MW) *See Table 9*	3.94

Resource-specific maintenance adder = default maintenance adder * Pmax of resource

= $3.94 * 50

= $197/run-hour

Appendix D: Supporting Calculations

See Excel file attached to this paper.

Appendix E: Nexant Report Supporting VO Adder Values

See the report starting on the following page.

REPORT

Variable Operations Costs Report - Version 2

Submitted to: California Independent System Operator

Contents

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 H_2S Abatement Costs

A paper titled "Geysers Power Plant H_2S 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 H_2S 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://ieaghg.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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