



# California Independent System Operator

Variable Operations and Maintenance Costs  
January 8, 2019



Reimagine tomorrow.

# Agenda

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- **Introduction and Background**
- **Cost Definitions**
- **Methodology**
- **Data Sources**
- **Variable O&M Cost Information**
  - Coal and Natural Gas Fired Units
  - Combustion Turbine and Combined Cycle Units
  - Nuclear and Advanced Nuclear Units
  - Renewable Generating Units with VOM
  - Plants without Variable Operations and Maintenance Costs
- **Q&A**

# Introduction and Background

# Objectives

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## Project Objectives

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

# Project Requirements

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## Requirements

- VOM values to be developed for generator types that have a significant market presence in the Western Interconnection; some future types specified by CASIO
- VOM values should adhere to the CAISO's definition of Variable Operations and Maintenance costs
- Since VOM 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 a class but not all
- For generators whose variable O&M costs are different, the CAISO is expected to continue its past practices of working with generator owners to develop generator-specific VOM values.
- To the extent possible, VOM values should be developed using publicly available information.
- The VOM costs developed should be representative of the costs in the year 2019

# Cost Definitions

# Cost Definitions

## No standard definitions in use in the industry

- For Fixed vs. Variable costs or
- For Variable costs that vary with production vs. starts or hours
- Important to use definitions consistent with CAISO market

## Cost Categories of Interest

- Variable Operations and Maintenance cost consistent with CAISO definition of VOM - Cost of Consumables and Waste Disposal
- VOM examples:
  - 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
- Important to include only costs consistent with CAISO definitions/market



# Cost Definitions (continued)

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## Cost Categories of Interest

- Major Maintenance costs - required to maintain the generating unit in an efficient and reliable condition
  - Scheduled major overhaul expenses for maintaining prime mover
  - Major maintenance labor expenses
  - Major maintenance spare parts costs
  - Balance-of-Plant (BOP) major maintenance costs that cannot be performed with routine maintenance or while in commercial operation



# Cost Definitions (continued)

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## Cost Categories of Interest

- Other Maintenance costs - required to maintain the generating unit in an efficient and reliable condition
  - Maintenance not normally performed during extended periods of shutdown; includes
    - Maintenance of equipment such as water circuits, feed pumps, main steam piping, and demineralizer systems
    - Maintenance of other plant equipment, which includes service water, DCS, condensate system, air filters, and plant electrical
    - Maintenance of miscellaneous plant equipment such as communication equipment, instrument and service air, and water supply system

## Cost Definitions (continued)

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### **VOM Cost Values include those costs that**

- Vary directly with the level of production
- Include consumables and waste disposal
- Do not include Major Maintenance Costs
- Do not include Other Maintenance Costs

# Methodology

# Methodology

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## VOM Cost Estimation Methodology

- Rely on Public Information as much as possible
- Find sources that include VOM information consistent with CAISO definition; VOM that did not include MM or OM costs
- Favor sources that allow bottom up estimation approach
- Revise data components, if appropriate, to apply to a majority of generators
- When such disaggregated sources were not available used sources with aggregated data which were then disaggregate into VOM and other costs
- In some cases estimates were developed using reference data from related plants
- Final step was to escalate the costs to 2019 as needed (referred to as 2019\$)

# Methodology to Escalate Costs to 2019

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**Considering the broad range of cost that can be included in any given VOM value we chose to use a simple escalation approach**

- The approach used is based upon US Consumer Price Index published periodically by the US Bureau of Labor Statistics
- Basic approach is to use the ratio of the CPI values for the source year and the target year (2019)
- For example, to escalate 2016 costs to 2019, the 2016 data would be multiplied by the ratio of two CPI values – the CPI values for 2019 and 2016
- To obtain 2019 data, the 2016 data is multiplied by the ratio  $\text{CPI}(2019)/\text{CPI}(2016)$

# Data Sources

# Data Sources

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**Many data sources were used in the development of the estimated VOM values including the following examples:**

- ISOs (NY, NE, PJM) Cost of New Entry (CONE) Study Reports
  - Detailed engineering based studies for new construction costs
  - Most useful for generators with GT and CC component
- Sargent and Lundy Study for New Coal Fired Plants
  - Detailed engineering based studies for new construction costs with detailed breakdown of VOM
  - Most useful for coal fired generators and developing some components for other fossil generation
- Geothermal H<sub>2</sub>S Abatement Costs
  - Published in the Geothermal Research Council Transactions, Vol. 34, 2010
  - Based upon actual VOM costs at the Geysers Power Plant in CA

## Data Sources (continued)

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**Many data sources used in the development of the estimated VOM values including the following examples:**

- EIA Annual Energy Outlook Reports
  - 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)
  - About every three years EIA commissions an external consultant to perform a new study to develop EPC costs and O&M costs; between these studies values are escalated
  - The periodic engineering studies include construction costs and fixed and variable maintenance costs; VOM estimates included major maintenance costs

**These and other data sources along with links are included in the Report**

# Generator VOM Data

# Generator VOM Data

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**VOM estimates for 2019 are included in the report for the following generator groups**

- Coal and Natural Gas Fired Units
- Combustion Turbine and Combined Cycle Units
- Nuclear and Advanced Nuclear Units
- Renewable Generating Units with VOM
- Plants without Variable Operations and Maintenance Costs

# Information Provided

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## Data provided for each generator group in the report

- Potential Variable Operations and Maintenance Cost default values for generating plants covered by report are shown in several tables in Section 3 of the Report.
- Generators have been grouped such that similar generators are listed in the same section and cost table.

## The information for each group 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 VOM value for generators in the group
- A table that list the Generator Types included in the group and the VOM costs in \$/MWh in 2019 dollars

# Coal and Natural Gas VOM Data

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## **Group includes**

- A number of existing coal plant types (sub and supercritical),
- Advanced coal fired plants, Integrated Coal Gasification and Combined Cycle plants and
- Conventional sub-critical natural gas fired plants

## **Cost Components**

- Water used in water/steam cycle and other processes in the generation facility that utilize water,
- Chemicals associated with the plant emissions control processes,
- Waste treatment and disposal and
- Other miscellaneous consumable costs

## **More Important Data Sources**

- 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

# Coal and Natural Gas VOM Data

## Group VOM 2019 Values

Plant Type	Variable O&M Cost
Coal Plant - Pulverized Coal – Subcritical	\$2.69/MWh
Coal Plant - Pulverized Coal – Supercritical	\$2.64/MWh
Coal Plant - Ultra-Super-Critical Coal Plant	\$2.60/MWh
Coal Plant - Super-Critical with 90% Carbon Capture and Sequestration (CCS)	\$5.21/MWh
Integrated Coal Gasification Combined-Cycle (IGCC)	\$1.57/MWh
Oil/Gas Steam Plant – Subcritical	\$0.32/MWh

# Combustion Turbine and Combined Cycle VOM Data

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## **Group includes combustion turbine generator types in simple and combined cycle and advanced arrangements with carbon sequestration:**

- 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.
- Combined Cycle Heavy Duty Frame H – This category represents the new CCs entering into service. The values were derived based on a 383 MW Siemens 1 x 1 x 1 SGT6-8000H Combined Cycle Power Plant.
- Advanced Combined Cycle with Carbon Capture and Sequestration. This category represents advanced power plants that use the latest combined cycle technology along with 90% Carbon Capture and Sequestration (CCS) Technology. The plant size is 860MW Gross and 789 MW net.
- Combustion turbines - E Class - This category represents the older frame gas turbines that are in service (Frame B/E) in WECC. The values were derived based on a 74MW, GE Frame 7000E Simple Cycle Power Plant.

# Combustion Turbine and Combined Cycle VOM Data

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**Group includes combustion turbine generator types in simple and combined cycle and advanced arrangements with carbon sequestration (continued):**

- 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 - H Class - This category represents the new frame combustion turbines entering the WECC region. The values were derived based on a 337 MW GE 7HA.02 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.
- Combustion turbines (Aeroderivative) LMS100 – This category represents the new/recent aeroderivative combustion turbines in the WECC region. The values are based on a 100 MW GE LMS100 PA Simple Cycle Power Plant.

# Combustion Turbine and Combined Cycle VOM Data

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## Cost Components

- Water used in water/steam cycle,
- Chemicals associated with the water and plant emission's control processes,
- Chemicals required for CO2 capture for the Advanced Combined Cycle with CCS Unit and
- Other miscellaneous consumable costs

## More Important Data Sources

- ISO CONE Reports
- Parson Brinkerhoff Report for the CCS O&M

# Combustion Turbine and Combined Cycle VOM Data

## Group VOM 2019 Values

Plant Type	Variable O&M Cost w/o SCR	Variable O&M Cost w SCR
Combined Cycle CC Heavy Duty Frame F	\$0.17/MWh	\$0.26/MWh
Combined Cycle Heavy Duty Frame H	\$0.17/MWh	\$0.38/MWh
Advanced Combined Cycle with Carbon Capture and Sequestration		\$2.64/MWh
Combustion Turbines - E Class	\$0.47/MWh	\$1.58/MWh
Combustion Turbines - F Class	\$0.29/MWh	\$0.82/MWh
Combustion Turbines - H Class	\$0.29/MWh	\$0.82/MWh
Combustion turbines (Aeroderivative) LM6000	\$0.70/MWh	\$1.88/MWh
Combustion turbines (Aeroderivative) LMS100	\$0.72/MWh	\$1.82/MWh

# Nuclear and Advanced Nuclear VOM Data

## Nuclear Group :

- This group includes existing conventional nuclear plants with ratings of about 1100 MW and an advanced nuclear plant with a rating of 1137 MW.
- The primary source of data used to develop these VOM cost estimates was the EIA reports

Plant Type	Variable O&M Cost
Nuclear Plant Size 1100 MWs	\$1.87/MWh
Advanced Nuclear Plant 1137 MW	\$1.96/MWh

# Renewable Generating Units with VOM

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## Group includes:

- Plants in this group are all renewable in nature, except the Fuel Cell and the Internal Combustion Engine generator which are primarily fueled by natural gas.
- Group includes geothermal plants, biomass plants operating on agriculture waste, two solar thermal power plants one with and one without storage, a fuel cell, a land fill gas generation plant and an internal combustion engine plant.

## Cost Components

- Geothermal Power Plant – costs associated with H<sub>2</sub>S 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 NO<sub>x</sub> control, ash disposal costs and other miscellaneous consumables and waste costs.
- Solar Thermal Power Plant w/o storage – Cost of water and water chemicals for the steam cycle and cooling tower and other miscellaneous consumables costs.

(continued)

# Renewable Generating Units with VOM

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## **Cost Components (continued)**

- Solar Thermal Power Plant with storage – Cost of water and water chemicals for the steam cycle and cooling tower, cost of Nitrogen (or inert gas) blanketing of the molten salt storage tanks and other miscellaneous consumables
- Fuel Cell – cost of fuel cell stack (or membrane) replacement that is directly proportional to MWh generated
- 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.

## **Primary Data Sources Cost Components**

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

# Renewable Generating Units with VOM

## Group VOM 2019 Values

Plant Type	Variable O&M Cost
Geothermal Power Plant	\$1.16/MWh
Biomass Power Plant	\$1.65/MWh
Solar Thermal Power Plant w/o storage	\$0.24/MWh
Solar Thermal Power Plant with storage	\$0.26/MWh
Fuel Cell	\$37.7/MWh
Land Fill Gas	\$1.21/MWh
Internal Combustion Engine	\$1.10/MWh

# Plants Without VOM Cost Estimates

The VOM cost estimate (based upon the CAISO VOM definition) for the following plants is zero

Plant Type
Small Hydro
Large Hydro
Pumped Storage
Solar PV of all sizes
Wind Generators
Battery Storage Units

Questions/Comments?