

PJM Manual 15:

Cost Development Guidelines

Revision: 36

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Prepared by
Cost Development Subcommittee

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Approval

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Glen Boyle, Chairman

Cost Development Subcommittee

Current Revision**Administrative Change (10/05/2020):**

- Restoring previously approved language in sections 2.3.3, 2.3.6, 2.3.7 and 2.3.8 that was mistakenly left out of the version 36 published on 9/4/2020.

Revision 36 (09/01/2020):

- Section 2.3:
 - o Updates to reflect revised Fuel Cost Policy rules from Operating Agreement, Schedule 2 based on key work activities from MIC Special Session: Fuel Cost Policy Enhancements
 - o Removal of Annual Review Process
 - o Updates to Fuel Cost policy review process

Section 1: Introduction

1.1 About PJM Manuals

The PJM Manuals are the instructions, rules, procedures, and guidelines established by PJM for the operation, planning, and accounting requirements of PJM and the PJM Markets.

For a complete list of all PJM manuals, go to the Library section on PJM.com.

1.2 How to Use This Manual

The **PJM Manual 15: Cost Development Guidelines** is one in a series of the PJM Manuals. This Manual is maintained by the [PJM Cost Development Subcommittee \(CDS\)](#) under the auspices of the PJM Market and Reliability Committee (MRC).

To use this Manual, read sections one and two then go to the chapter for unit type for possible additional information.

All capitalized terms that are not otherwise defined herein shall have the same meaning as they are defined in the Amended and Restated Operating Agreement of PJM Interconnection, L.L.C. (PJM Operating Agreement), PJM Open Access Transmission Tariff (PJM Tariff) or the Reliability Assurance Agreement Among Load Serving Entities in the PJM Region. Throughout this manual, the term MMBtu is one million British Thermal Units (BTU).

1.3 The intended audiences for this Manual:

- Market Seller
- PJM staff
- MMU
- Regulators

1.4 What is in this Manual?

- A table of contents that lists two levels of subheadings within each of the sections
- An approval page that lists the required approvals and a brief outline of the current revision
- Sections containing the specific guidelines, requirements, or procedures including PJM actions and Market Seller actions
- Attachments

1.5 Cost Development Subcommittee Mission

The CDS reports to the MRC and is responsible for developing, reviewing, and recommending procedures for calculating the costs of products or services provided to PJM at a cost-based rate for Market Sellers. CDS responsibilities can be found in the CDS' [charter](#).

1.6 Purpose of this Manual

This document details the standards recognized by PJM for determining cost components for markets where products or services are provided to PJM at cost-based rates, as referenced in Schedule 1, Section 6 of the PJM Operating Agreement.

1.6.1 Reason for Cost Based Offers: Market Power Mitigation

The following material is provided for background and should be used for information only. Structural market power is the ability of seller, or a group of sellers, to alter the market price of a good or service for a sustained period. To mitigate the potential exercise of market power, market rules can offer cap units in various markets. The Three Pivotal Supplier (TPS) test is used to determine if structural market power exists in a given market. If structural market power is found to exist, some Market Sellers may be mitigated to cost-based offers to prevent any exercise of that market power.

The TPS test is a test for structural market power. The test examines the concentration of ownership of the supply compared to the level of demand. The test does not examine the competitiveness of offers or other factors.

The general concept of the TPS test is to control a constraint; a certain amount of MW of relief is needed. If there are not enough MWs to satisfy the constraint without using the top two suppliers' output plus the output of the supplier being tested, then those three suppliers are jointly pivotal. According to the criteria utilized by the TPS test, because the supply can be constrained by those three owners and the demand could potentially not be satisfied, they are considered to have structural market power. If any one supplier fails, then the top two suppliers also fail.

A test failure means that the ownership of the supply needed to meet is concentrated among few suppliers and therefore those suppliers have the potential to exercise market power or structural market power. It does not mean those suppliers are attempting to exercise market power.

A test failure triggers mitigation as a preventative step in the event of a concentration of ownership. If a generator is brought on for constraint control and its supplier fails a TPS test, then the unit is dispatched at the lower of the cost or price offer. The purpose of this Manual is to outline the development of the cost-based offer to ensure that PJM Members who own or control a generating unit(s) with structural market power cannot exercise it.

1.7 Components of Cost

This Manual is designed to instruct Market Sellers on how to develop their cost based offers. A Market Seller who is required to submit a cost-based offer for a resource shall be responsible for the development and accuracy of all information to support the calculation of a resource's cost-based offer and shall provide such information to PJM or the MMU, either directly or indirectly through an agent or other entity, upon request or as required by applicable PJM market rules. These cost-based offers are used by PJM to schedule generation in cases in which structural market power is found to exist. PJM uses the information provided from Market Sellers to determine each unit's production costs.

Production costs are the costs to operate a unit for a particular period. Several different cost components are needed to determine a generating unit's total production cost. The total production cost includes:

- Start-up Cost
- No-Load Cost
- Incremental costs (energy cost per segment of output range)

Production costs have a direct impact on which units are scheduled by PJM. In general, generation will be scheduled to achieve the lowest possible overall costs to the system.

The following material is provided for background and should be used for information only.

1.7.1 Generator offer curves

Generator offer curves are representations of a generator's willingness to provide energy. Offer curves are used in determining incremental and total production costs. An offer curve can have up to ten points defined. The first point describes the lowest MW amount offered for a unit. The offer curve may be a smooth line or a block curve depending on how the points between each segment are calculated. The Market Seller can determine how the slope of the offer curve is defined; however, the slope must be monotonically increasing.

1.7.2 Start-up Cost

Start-up Costs are defined as the unit costs to bring the boiler, turbine and generator from shutdown conditions to the point after breaker closure which is typically indicated by telemetered or aggregated state estimator MWs greater than zero and is determined based on the cost of start fuel, total fuel-related cost, performance factor, electrical costs (station service), start maintenance adder, and additional labor cost if required above normal station manning. Start-up Costs can vary with the unit offline time being categorized in three unit temperature conditions: hot, intermediate and cold. Start-up Cost is a dollar cost and is incurred once each time the unit operates regardless of the period of operation. See Start-up Cost in Section 2.4.

1.7.3 No Load Cost

No-Load Fuel (MMBtu/hour) is the total fuel to sustain zero net output MW at synchronous generator speed.

No-Load Cost (\$/hour) is the hourly cost required to create the starting point of a monotonically increasing incremental offer curve for a generating unit. The calculated No-Load Cost may have to be adjusted to ensure that the slope of the Generator Offer Curve is monotonically increasing.

1.7.4 Incremental Cost

Hourly production cost is the cost per hour to operate a unit assuming a start has already occurred. It is calculated by summing all costs, which are incurred during one hour of operation including the hourly No-Load Cost and the incremental energy cost.

The incremental energy cost is the cost per MWh to produce all of the energy segments above the Economic Minimum level (minimum generation level with the unit available for economic dispatch). No-Load Costs are not included in the incremental costs. It is calculated by summing the cost of each segment of energy in the unit's incremental cost curve up to the generation level. This cost is a dollar per hour (\$/MWh) rate.

1.7.5 Total Production Cost

Total production cost is calculated by adding all of the costs associated with starting a unit and operating it over a period. Total production costs include two categories of costs: Start-up Costs and hourly production costs.

To determine the total production cost of a unit, the following formula is used:

$$\text{Total Production Cost} = \text{Startup Costs} + \sum_0^x \text{Hourly Production Costs}$$

Where x= Number of hours a unit is run at a certain MW level

It is important to remember that PJM will schedule generation day-ahead based on the above but dispatch using the incremental (marginal) cost, as represented by its generation offer. The incremental (marginal) cost will represent the cost to generate the next MW from the unit. See Heat Rate in Section 2.1, Performance Factor in Section 2.2, Performance Factors in Section 2.2, and Fuel Cost in Section 2.3, No-Load Cost in Section 2.5 and 2.6 Maintenance Cost.

1.8 Cost Methodology and Approval Process

A Market Seller which seeks to obtain an exemption, exception or change to any time frame, process, methodology, calculation or policy set forth in this Manual, or the approval of any cost or methodology that is not specifically permitted by this Manual not related to the Fuel Cost Policy, shall submit a request to PJM and MMU for consideration and determination along with documentation supporting the request.

After receipt of such a request, PJM and MMU will review the request and PJM will notify the Market Seller and MMU whether the request is approved no later than thirty (30) calendar days after submission of the request.

This process shall be referred to in this Manual as the “Cost Methodology and Approval Process.”

1.9 References

The references to other documents that provide background or additional detail directly related to the PJM Manual for **Cost Development Guidelines** are:

- PJM Manual for [Pre-Scheduling Operations \(M-10\)](#)
- PJM Manual for [Energy & Ancillary Services Market Operations \(M-11\)](#)
- PJM Manual for [Generator Operational Requirements \(M-14D\)](#)
- PJM Manual for [Open Access Transmission Tariff Accounting \(M-27\)](#)
- PJM Manual for [Operating Agreement Accounting \(M-28\)](#)
- [Markets Gateway User Guide](#)
- [Markets Database Dictionary](#)
- [Opportunity Cost Calculator](#)
- A Review of Generation Compensation and Cost Elements in the PJM Markets

- Member Information Reporting Application (MIRA)

Section 2: Policies for All Unit Types

This section contains information that is relevant for the development of a cost offer for all types of units.

2.1 Heat Input and Rates

Heat Input equals a point on the heat input curve (in MMBtu/hr) describing the resource's operational characteristics for converting the applicable fuel input (MMBtu) into energy (MWh). Heat Input curves are typically obtained via plant performance testing or from the original equipment manufacturer.

Heat Rate equals the MMBtu content of the heat input divided by the MWh of power output. The smaller the heat rate value the greater the efficiency. The heat rate can also be referred to as the input-output function.

$$\text{Total Heat Rate} = \frac{\text{MMBtu}}{\text{MWh}} = \frac{\text{Heat Input}}{\text{Net MW}}$$

The Incremental heat rate is the relationship between an additional MW of output and the heat input necessary to produce it. Graphically, the incremental heat rate can be determined from the ratio of the change in fuel input to the change in unit MW output; which is the slope of the input/output curve. Mathematically, the incremental heat rate curve can be expressed as the first derivative of the heat rate curve (input heat versus MW output).

$$\begin{aligned} \text{Incremental Heat Rate} &= \Delta \text{MMBtu} / \Delta \text{MWh} \\ &= (\text{Change in Fuel Going in}) / (\text{Change in Energy Coming Out}) \\ &= (d_y / d_x) \text{ Total Heat Rate} \end{aligned}$$

Economic Minimum is the lowest level of energy in MW the unit can produce and maintain a stable level of operation under normal operation.

Economic Maximum is the highest unrestricted level of energy, in MW, that the operating company operates the unit under normal operation. This represents the highest output available from the unit for economic dispatch.

2.1.1 Heat Input and Rate Policy

All Market Sellers shall develop Heat Input curves. These heat input curves show heat input in MMBtu/hr from burning fuel versus MW output for each of their generating units. The heat input curves then serve as the basis for the theoretical incremental heat rate curves for fuel consumption and performance factor development. A Market Seller is allowed to use either net or gross MW values in determination of the incremental heat rate curves as long as gross or net MW value consistency is maintained throughout the cost development process. Heat rate information provided to the Office of the Interconnection should be on a net MW basis.

- Heat input curves (one curve per fuel type for each operating mode) will be based on design or comparable unit data modified by actual unit test data (when available).
- Data for the heat input curve development, ideally, should include Economic Minimum and Economic Maximum MW points. The heat input curve will be fitted from available data.

- This heat input curve (or curves) will be used as the basis for incremental heat rate curves, incremental costs and performance factor calculations.

2.2 Performance Factors

Performance Factor is the calculated ratio of actual fuel burn to either theoretical fuel burn (design heat input) or other current tested heat input. Actual burn may vary from standard burn due to factors such as unit age or modification, changes in fuel properties, seasonal ambient conditions, etc.

$$\text{PerformanceFactor} = \frac{\text{TotalActualFuelConsumed}}{\text{TotalTheoreticalFuelConsumed}}$$

The Performance Factor shall be calculated on either the total fuel consumed or a monthly spot check test basis. The Performance Factor for nuclear and steam units shall be reviewed (and updated if changed) at least once every twelve months. The Performance Factors for combustion turbine ("CT"), diesel units, and combined-cycle ("CC") units shall be updated at least once during:

- Twelve months, or
- The year in which a unit reaches 1,000 accumulated running hours since its last Performance Factor update, whichever represents a longer period, not to exceed five years.

Requests for exemptions from these periods should be submitted to PJM and the MMU for evaluation pursuant to Section 2.3. The overall Performance Factor can be modified by a seasonal Performance Factor to reflect ambient conditions.

2.2.1 Engineering Judgment in Performance Factors

The calculated performance factor may be superseded by estimates based on sound engineering judgment. If the period during which estimated performance factors are used exceeds three months, documentation concerning reasons for the override must be maintained and available for review.

2.2.2 Higher Heating Value of Fuel

Higher Heating Value of Fuel - the amount of heat released by a specified quantity once it is combusted and the products have returned to an original temperature. Higher Heating Value (HHV) of fuel may be based on any of:

- As burned test
- In stock test
- As received test
- As shipped test
- Contract value
- Seller's invoice
- Seller's quote

- Nominal value based on Industry Standard

2.2.3 Calculation Methods of Performance Factors

There are three options available for use in determining a unit's performance factor:

1. Total Fuel
2. Separate
3. Fixed start approach

These three methods are described with their corresponding equations as follows:

Performance Factors are used in calculating start fuel as well as operating fuel. When the (1) **total fuel approach** is used, the Performance Factor would represent the ratio:

$$PerformanceFactor = \frac{TotalActualFuelConsumed}{TotalTheoreticalFuelConsumed}$$

With the total fuel approach, fuel quantities measured during start tests should be modified by the Performance Factor in effect at the time of the test so that theoretical or standard start fuel quantities will be on the same basis as the standard operating fuel quantity.

Conditions encountered during the start of certain units may make it preferable to assign separate Performance Factors for start and operating fuel. If (2) **separate Performance Factors** are calculated for start fuel prior to calculating the "operating fuel" Performance Factor, this Operating Fuel Performance Factor will represent the ratio:

$$OperatingFuelPerformanceFactor = \frac{TotalActualFuelConsumed - ActualStartFuelConsumed}{TotalTheoreticalFuelConsumed - TheoreticalStartFuelConsumed}$$

Due to the variability and difficulty in measuring actual start fuel, a Market Seller may choose to set a (3) **fixed start Performance Factor of one**, implicitly assigning all performance variations to no-load and incremental loading costs. In order to account for all fuel actually consumed, the operating fuel Performance Factor will represent the ratio:

$$OperatingFuelPerformanceFactor = \frac{TotalActualFuelConsumed - TotalTheoreticalStartFuelConsumed}{TotalTheoreticalFuelConsumed - TotalTheoreticalStartFuelConsumed}$$

Where total theoretical start fuel consumed = fuel quantity used in the Start-up Cost calculation

2.2.4 'Like' Units for Performance Factors

An average Performance Factor may be calculated and applied for groups of like units burning the same type of fuel. Please see the Generation sections for further detail of 'like' units.

2.3 Fuel Cost Policies and Guidelines

A Market Seller may only submit a non-zero cost-based offer greater than the temporary cost offer methodology if it has a PJM-approved Fuel Cost Policy consistent with each fuel type on which the resource can operate in accordance with Section 2.3.1 of this manual and Operating Agreement, Schedule 2. Regulation only resources do not require a Fuel Cost Policy. The Fuel Cost Policy will be submitted in MIRA, or other system(s) made available for submission of such data. Submission to MIRA, or other system(s) made available is considered submission to PJM

and the MMU. Market Sellers that offer a schedule with more than one fuel type must ensure that the portion of the offer for each fuel type is in accordance with the PJM approved Fuel Cost Policy.

2.3.1 Submission of and/or Modifications to Fuel Cost Policies

Prior to expiration of a Fuel Cost Policy, all Market Sellers will be required to either submit to PJM and the Market Monitoring Unit an updated Fuel Cost Policy that complies with this Operating Agreement, Schedule 2 and PJM Manual 15, or confirm that their expiring Fuel Cost Policy remains compliant.

A Market Seller shall submit a new or updated Fuel Cost Policy:

- If a Market Seller has an approved Fuel Cost Policy currently in place and needs to alter it in order to conform it to the provisions of this Manual or any applicable provisions of PJM's governing documents,
- If any action by a governmental or regulatory agency external to a Market Seller results in a need for the Market Seller to change its method of fuel cost calculation,
- If there are any material changes to Fuel Cost Policy,
- If PJM requests a Market Seller to submit an updated Fuel Cost Policy, or
- If a Market Seller will be entering a non-zero cost offer for a new or existing resource without an approved policy into PJM's energy markets.

The Market Seller shall notify PJM and the MMU that an update to an existing Fuel Cost Policy or the need for a Fuel Cost Policy for a new resource is required at the earliest possible opportunity. If PJM requests the Market Seller to submit an updated Fuel Cost Policy, then the expiration of the Market Seller's current Fuel Cost Policy shall follow the process set forth in Section 2.3.1.2. The Market Seller shall provide an updated policy to PJM and the MMU:

- For new resources, following the process delineated in Operating Agreement Schedule 2 Section 2.2 (a).
- For resources transferred to another Market Seller, the new Market Seller shall submit a Fuel Cost Policy to PJM and MMU for review prior to transfer or an alternative date agreed to by PJM. The new Market Seller may use the temporary cost offer methodology described in Section 2.3.1.3 for making cost based offers, as an alternative to offering zero, while a new policy is under evaluation. Note: Changes in dispatch agent do not require submission of a new policy.
- For existing resources, the Market Seller may use the temporary cost offer methodology described in Section 2.3.1.3 for making cost-based offers, as an alternative to offering zero, while the requested update or new policy is under evaluation, in the absence of an approved Fuel Cost Policy.

2.3.1.1 PJM and MMU Review Timelines and Fuel Cost Policy Effective Date

The MMU shall have an initial 10 Business Days to review a submitted Fuel Cost Policy and an additional 5 Business Days every time the Market Seller revises the Fuel Cost Policy. At any time, the Market Seller may request:

- PJM begin its review prior to the completion of the MMU review; or

- PJM delay its review until after the completion of the MMU review.

Immediately following the MMU's review, or at the Market Seller's request for PJM to review, PJM shall have 20 Business Days to review a submitted Fuel Cost Policy and an additional 5 Business Days or an agreed upon date between PJM and the Market Seller every time the Market Seller revises the Fuel Cost Policy. If PJM rejects a Market Seller's updated Fuel Cost Policy, PJM must include an explanation for why the Fuel Cost Policy was rejected in its written notification. All approved Fuel Cost Policies will have an effective date of the next operating day following approval, or a later date as indicated by PJM in its written notification to the Market Seller and MMU. The approved policy will be in effect until superseded or expired.

2.3.1.2 Expiration of a Fuel Cost Policy

(a) PJM, in consultation with the Market Seller and with timely input and advice from the Market Monitoring Unit, may:

- i. Update the Market Seller's Fuel Cost Policy expiration date, with at least 90 days notification to the Market Seller, due to a business rule change in the PJM governing documents.
- ii. Immediately expire the Market Seller's Fuel Cost Policy with written notification to the Market Seller when a change in circumstance causes the Market Seller's fuel pricing and/or cost estimation method to be no longer consistent with the approved Fuel Cost Policy, this Operating Agreement, Schedule 2 or PJM Manual 15.

(b) If the Market Seller of a generation resource that has transferred from another Market Seller does not affirm the current approved Fuel Cost Policy on file, then such Fuel Cost Policy shall expire upon the generation resource's transfer of ownership.

(c) PJM shall notify the Market Seller and the Market Monitoring Unit in writing the updated Fuel Cost Policy expiration date and rationale for changing the expiration date.

(d) On the next business day following immediate expiration of a Fuel Cost Policy, the Market Seller may only submit a cost-based offer of zero or a cost-based offer that is consistent with the temporary cost offer methodology in Section 2.3.1.3 until a new Fuel Cost Policy is approved by PJM for the relevant resource.

(e) Market Sellers who have a Fuel Cost Policy that has been immediately expired by PJM will be provided a three (3) Business Day rebuttal period, starting from the date of expiration, to submit supporting documentation to PJM demonstrating that the expired Fuel Cost Policy accurately reflects the fuel pricing and/or estimation method documented in the previously approved Fuel Cost Policy that was expired. However, if, upon review of the Market Seller's supporting documentation, PJM determines that the expired policy accurately reflects the Market Seller's actual methodology used to develop the cost-based offer that was submitted at the time of expiration and that the Market Seller has not violated its Fuel Cost Policy, then PJM will make whole the Market Seller via uplift payments for the time period for which the applicable Fuel Cost Policy had been expired and the generation resource was mitigated to its cost-based offer.

2.3.1.3 Temporary Cost Offer Methodology

The temporary cost offer methodology is intended to serve as a temporary Fuel Cost Policy for Market Sellers negotiating a new policy with PJM in good faith for the following:

- Generation resources that initiate participation in the PJM Energy Market

- Generation resources transferring from one Market Seller to another
- If the Market Seller does not have an approved Fuel Cost Policy in place upon expiration of its previously approved policy

The temporary cost offer methodology shall be comprised of the index settle price at the PJM assigned commodity pricing point multiplied by heat input curves submitted by the Market Seller, in accordance with Section 2.1:

- For generation resources that opt-out of intraday offers, the last published closing index settle price shall be used for all hours of the Operating Day
- For generation resources that opt-in to intraday offers, index settle prices shall be based on the last published closing settle price for a 11 hours of the Operating Day to reflect the:
 - o Last published closing settle price, if decreased, for hours ending 11 through 24 for natural gas
 - o Last published closing settle price, if decreased, for all hours of the Operating Day for all other fuel types

The commodity pricing point and index publication source shall be assigned by PJM in consultation with the Market Seller and with timely input and advice from the IMM.

2.3.2 Fuel Cost Calculation

The method of calculation of fuel cost may be updated by the Market Seller no more frequently than once every 12 months, on a rolling basis, unless required to be changed per Section 2.3.1.

Each Market Seller must review and document its fuel costs in MIRA, or other system(s) made available for submission of such data, at minimum once per month (12 times per year). Additionally, each review must occur within forty (40) days of the preceding review. The results of this review will be used to determine whether a fuel cost update and subsequent change to the Fuel Cost Policy is necessary.

The method of calculation of fuel cost in MIRA, or other system(s) made available for submission of such data, may include the use of actual fuel prices paid, e.g. the contract price paid for fuel, or the spot price for fuel. The contract price for fuel must include the locational cost of fuel for the generating unit. The source used for spot price for fuel must be publicly available and reflect the locational cost of fuel for the generating unit. The locational cost of fuel shall include specification of any additional incremental costs of delivery for the generating unit.

Each Market Seller will be responsible for establishing its own method of calculating delivered fossil fuel cost, limited to inventoried cost, replacement cost or a combination thereof, which reflects the way fuel is purchased or scheduled for purchase.

The method of calculation will be consistent with the current effective Fuel Cost Policy and may only be changed by receipt of final approval pursuant to Section 2.3.1. Fossil fuel cost adjustments compensating for previous estimate inaccuracies should not be considered when determining the basic fossil cost component of Total Fuel Related Cost.

Units that co-fire more than one fuel shall weight average the cost of the fuel on a per MMBtu basis. Units that fire solid waste, bio-mass, or landfill gas shall include the cost of such fuel when calculating the average even when the cost of such fuel is negative. However, cost offers for units that fire solid waste, biomass, or landfill gas are not required to be less than zero.

2.3.3 Total Fuel Related Costs

Total Fuel Related Cost is the sum of fuel costs, fuel related cost, emission allowance cost, and maintenance cost.

$$\text{TotalFuelRelatedCosts} =$$

$$\text{FuelCosts} + \text{FuelRelatedCosts} + \text{SO}_2 \text{ AllowanceCost} + \text{CO}_2 \text{ AllowanceCost} + \text{NO}_x \text{ AllowanceCost} + \text{MaintenanceAdder}$$

Escalation of previous year dollar amounts is permitted when the term of calculation exceeds twelve months. When used, escalation indexes will be the same as those developed for calculation of incremental Maintenance Adders.

2.3.4 Types of Fuel Costs

Basic Fuel Cost – The cost of fuel calculated as stated in the Market Sellers’ Fuel Cost Policy (excluding fixed lease expenses).

Note:

Basic Fuel Cost for each unit type will be addressed in subsequent sections.

Incremental Energy Cost –The incremental heat or fuel required to produce an incremental MWh at a specific unit loading level multiplied by the applicable Performance Factor, multiplied by the fuel cost plus the appropriate maintenance cost.

Total Cost – The total theoretical heat input minus the no-load heat input at a specific unit loading level, multiplied by the applicable Performance Factor, multiplied by the fuel cost plus the appropriate maintenance cost, plus the No-Load Cost.

2.3.5 Emission Allowances

Each unit that requires SO₂ /CO₂ /NO_x emission allowances (EAs) to operate may include in the unit's TFRC the cost (\$/MMBtu) of the EAs as determined in the Market Seller's Emissions Policy.

Each Market Seller must submit a policy that would state the method of determining the cost of SO₂ /CO₂ /NO_x EAs for evaluation pursuant to the Cost Methodology and Approval Process. An example of the calculation must be included in the policy. The method of calculation may be changed only after evaluation pursuant to the Cost Methodology and Approval Process and should be updated at least annually

The period used for determining the projected SO₂ /CO₂ /NO_x discharge and the MMBtu’s burned must be included in the Market Seller's policy and may be based on historical or projected data.

For units that have dual fuel firing capability, a Market Seller should use different EA factors based on the SO₂ /CO₂ /NO_x emitted for each particular fuel or fuel mix.

NO_x /CO₂ emissions costs will be included in TFRC only during a NO_x /CO₂ compliance period and only by affected generating units. Details of the cost calculation methodology and example calculations will be contained in each Market Seller’s Emissions policy. Compliance requirements and dates may vary by geographic region.

Emissions adder calculations must be submitted to PJM and the MMU for review annually, in accordance with Operating Agreement Schedule 2 Section 3.

2.3.6 Leased Fuel Transportation Equipment

Leased Fuel Transportation Equipment Cost –Expenses incurred using leased equipment to transport fuel to the plant gate. If expenses are fixed, they must be excluded from fuel cost determination.

When calculating the Total Fuel Related Costs, fixed charges for transportation equipment (e.g., pipelines, train cars, and barges) should be excluded. Dollars that represent lease charges are considered fixed charges if the total amount to be paid over a period is fixed regardless of the amount of fuel transported. Should the terms of the lease agreement be such that there is a fixed charge plus a charge for every unit of fuel delivered, the "charge per unit of fuel delivered" should be included in the Fuel on Board (FOB) delivered cost or in the calculation of the Operating Costs as per the documented Fuel Cost Policy.

The above guideline applies when a unit, plant, or system is served totally by leased fuel transportation equipment. When fuel is supplied by both leased and common carrier fuel transportation systems, the common carrier rate should be included in the Fuel On Board (FOB) delivered cost or included in the calculation of the Operating Costs as per the documented Fuel Cost Policy of each Market Seller. This assumes that the leased fuel transportation equipment would serve base fuel requirements, while common carrier deliveries would change, based on incremental generation changes.

2.3.7 Operating Costs

The Operating Cost component of TFRC may be calculated based on a fixed or rolling average of values from one to five years in length, reviewed (and updated if changed) annually, or a rolling average from twelve to sixty months in length, reviewed (and updated if changed) monthly. Both the term and the frequency of the Operating Cost calculation shall be included in the Market Seller's Fuel Cost Policy. Allowable Operating Cost include lubricants, chemicals, Limestone, Trona, Ammonia, acids, caustics, water injection, and demineralizers. Operating Cost also include variable Title V and other applicable emissions fees. Market Sellers will be allowed to include additional operating costs via the Section 1.8 cost methodology and approval Process. Acceptable items will be added to M15 during the biennial revision.

2.3.8 Engineering Judgement in Fuel Cost Calculations

A Market Seller may apply engineering judgement to manufacturer's data, operating data or the results of start and run tests in order to derive the components of the total fuel cost. A record of the results of these determinations shall be kept on file by each Market Seller for use as a single, consistent basis for scheduling, operating, and accounting applications. These records shall be made available to PJM or the MMU upon request.

2.4 Start-up Cost

2.4.1 Start-up Cost Definitions

- **Start-up Cost (\$)** - The unit costs required to bring the boiler, turbine, and generator from shut-down conditions to the point after breaker closure which is typically indicated by telemetered or aggregated state estimator MWs greater than zero and is determined based on the cost of start fuel, total fuel-related cost, Performance Factor, electrical costs (station service), start maintenance adder, and additional labor cost if required above normal station manning levels.

$$\begin{aligned}
 \text{Start-upCost } (\$/\text{Start}) = & \\
 & [\text{StartFuel } (\text{MBtu}/(\text{Start})) * \text{TFRC}(\$/\text{MBtu}) * \text{PerformanceFactor}] \\
 & + [\text{StationService}(\text{MWh}) * \text{StationServiceRate}(\$/\text{MWh})] \\
 & + \text{StartMaintenanceAdder}(\$/\text{Start}) + \text{StartAdditionalLaborCost}(\$/\text{Start})
 \end{aligned}$$

- **Station Service Rate** – A \$/MWh value based on the 12-month rolling average off-peak energy prices updated quarterly by the Office of the Interconnection.
- **Start Fuel** - Fuel consumed from first fire of start process (initial reactor criticality for nuclear units) to breaker closing (including auxiliary boiler fuel) plus fuel expended from breaker opening of the previous shutdown to initialization of the (hot) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.
- Start Maintenance Adder – See Section 2.6
- **Start Additional Labor Cost** – Additional labor costs for startup required above normal station manning levels.

2.4.2 Engineering Judgment in Start Costs

A Market Seller may apply engineering judgment to manufacturers' data, operational data, or the results of start tests in order to derive the components of unit Start –up Cost. A record of the results of these determinations shall be kept on file by each Market Seller for use as a single, consistent basis for scheduling, operating, and accounting applications. These records shall be made available to the MMU or PJM upon request.

2.5 No Load

2.5.1 No-Load Definitions

No-Load Cost (\$/hour) - The hourly cost required to create the starting point of a monotonically increasing incremental offer curve for a generating unit.

2.5.2 No-Load Fuel

All Market Sellers shall develop No-Load Costs for their units. The no-load heat input may be determined by collecting heat input values as a function of output and performing a regression analysis. The heat input values as a function of output may be either created from heat rate test data or the initial design heat input curve for an immature unit.

The minimum number of points to develop a heat input curve shall be 2 points for a dispatchable unit with a variable output and 1 point for a unit with a fixed output.

Sufficient documentation for each generating unit's no-load point in MMBtu's (or fuel) per hour shall consist of a single contact person and/or document to serve as a consistent basis for scheduling, operating and accounting applications PJM and the MMU can verify calculation methods used are in accordance with the currently approved Fuel Cost Policy and the elements of Attachment B.

2.5.3 No Load Calculation

The initial estimate of a unit's **No-Load Cost (\$/Hr)** is the No-Load fuel Cost multiplied by the Performance Factor, multiplied by the (Total Fuel-Related Cost (TFRC))

$$NoLoadCost(\$ / Hour) = (NoLoadFuel * PerformanceFactor * TFRC)$$

The unit's generator offer curve must comply with PJM's monotonically increasing curve requirement. In some instances, the calculated No-Load Cost may have to be adjusted to ensure that the slope of the generator offer curve is monotonically increasing. The No-Load Cost adjustment is limited to a maximum difference of \$1/MWh between the unit's first and second incremental cost offers.

As an alternative to adjusting the No-Load Cost, No-Load Cost may also be calculated by subtracting the incremental cost (unit's Economic Minimum cost-offer value multiplied by MW value) at the unit's Economic Minimum point from the total cost (from the heat input at Economic Minimum value) at the unit's Economic Minimum point.

$$NoLoadCost(\$ / Hour) = \\ (EconomicMinimumHeatInput * PerformanceFactor * (TFRC + VOM)) - \\ (EconomicMinimumIncrementalCost (\$ / MWh) * EconomicMinimum (MW))$$

Note that if the unit of Variable Operations and Maintenance (VOM) cost is in terms of dollars per Equivalent Service Hours (ESH), the equation changes to:

$$NoLoadCost(\$ / Hour) = \\ (EconomicMinimumHeatInput * PerformanceFactor * TFRC) + VOM \\ - (EconomicMinimumIncrementalCost (\$ / MWh) * EconomicMinimum (MW))$$

When using No-Load Fuel to calculate No-Load Cost, the Market Seller must submit block average cost and cannot select "Use Offer Slope" when entering cost information into Markets Gateway. When using the alternative incremental cost method to calculate No-Load Cost, the Market Seller must submit incremental cost and select "Use Offer Slope" when entering cost information into Markets Gateway.

2.6 Variable Maintenance Cost

Variable Maintenance cost is the parts and labor expenses of maintaining equipment and facilities in satisfactory operating condition.

$$TotalMaintenanceCost_{NextYear} = \\ \left(AnnualMaintenanceCost * \frac{EscalationIndex_{NextYear}}{EscalationIndex_{CurrentYear}} \right) + \\ \left(AnnualMaintenanceCost * \frac{EscalationIndex_{NextYear}}{EscalationIndex_{LastYear}} \right) + \\ \left(AnnualMaintenanceCost * \frac{EscalationIndex_{NextYear}}{EscalationIndex_{LastYear-1}} \right) +$$

$$\dots + \left(\text{AnnualMaintenanceCost} * \frac{\text{EscalationFactor}_{\text{NextYear}}}{\text{EscalationIndex}_{\text{LastYear}-(\text{Maintenance Period}-1)} \right)$$

The Maintenance Adder is based on all available maintenance expense history for the defined Maintenance Period (See 2.6.3) regardless of unit ownership. Only expenses incurred as a result of electric production qualify for inclusion. The Maintenance Adder should be reviewed (and updated if changed) at least annually. Maintenance Adders may be included as part of the start cost, no load, or incremental energy offer. Maintenance Adders may be specified as \$/Start, \$/Hour, \$/MMBtu, \$/Equivalent Operating Hour (EOH), and/or \$/MWh.

The Maintenance Adder must be submitted to PJM and the MMU for review annually, in accordance with Operating Agreement Schedule 2 Section 4. Market Sellers may only use the PJM-approved Maintenance Adder in their unit's cost-based offer. Approved Maintenance and Emissions adders expire December 31 of the year following acceptance.

Market Sellers may only change the format of the Maintenance and Operating Cost adder (i.e., \$/MMBtu, \$/MWh, \$/Start, etc.) during the annual review period. In addition, once the Maintenance and Operating Cost adder is approved by PJM, the adder can only be included in the corresponding portions of the associated cost based energy offer components (i.e., No-Load Costs, Incremental Energy Costs, Start-Up Costs).

If a Market Seller feels that a unit modification or required change in operating procedures will affect the unit's Maintenance Adder, the revised Maintenance Adder must be submitted to PJM and the MMU for review and PJM-approval prior to use in cost-based offers.

2.6.1 Allowable Maintenance Expenses

Maintenance Costs are expenses incurred as a result of electric production. Allowable expenses can include repair, replacement, inspection, and overhaul expenses, including Long Term Service Agreements (LTSA), related to the following systems and/or their associated FERC accounts identified later in this manual – steam turbine, gas turbine, generator, boiler, Heat Recovery Steam Generators (HSRG), main steam, feed water, condensate, condenser, cooling towers, transformers, controls, and fuel systems. The major inspection and overhaul costs listed below in sections (a)-(c) are not exhaustive. A Market Seller may include costs in cost-based offers if those costs are similar to the costs outlined in this provision, so long as they are variable costs that are directly attributable to the production of electricity.

(a) Major inspections and overhauls of gas turbine and steam turbine generators include, but are not limited to, the following costs:

- turbine blade repair/replacement;
- turbine diaphragm repair;
- casing repair/replacement;
- bearing repair/refurbishment;
- seal repair/replacement and generator refurbishment;
- heat transfer replacement and cleaning;
- cooling tower fan motor and gearbox inspection;
- cooling tower fill and drift eliminators replacement;

- Selective Catalytic Reduction and CO Reduction Catalyst replacement;
- Reverse Osmosis Cartridges replacement;
- air filter replacement;
- fuel and water pump inspection/replacement.

(b) Major maintenance of gas turbine generators directly related to electric production include, but are not limited to:

- compressor blade repair/replacement;
- hot gas path inspections, repairs, or replacements.

(c) Major maintenance of steam turbine generators directly related to electric production include, but are not limited to:

- stop valve repairs;
- throttle valve repairs;
- nozzle block repairs;
- intercept valve repairs.

Maintenance Costs that cannot be included in a unit's cost-based offer are preventative maintenance and routine maintenance on auxiliary equipment like buildings, HVAC, compressed air, closed cooling water, heat tracing/freeze protection, and water treatment. Typically if the system is needed to remain in-service when the unit is not in operation expenses related to it cannot be included in a unit's cost based offer.

2.6.2 Labor Costs

Labor costs included in cost-based offers are limited to start-up costs for additional staffing requirements and do not include straight-time labor costs. Only staff overtime or contractor labor incurred for costs referenced in Section 2.6.1 of Manual 15 can be included in maintenance adder. Staff overtime or contractor labor to augment existing operations staff to run the unit cannot be included in the unit's cost-based offer.

2.6.3 Escalation Index

Escalation Index is the annual escalation index derived from the July 1 Handy - Whitman Index Table E-1, line 6, "construction cost electrical plant".

YEAR	INDEX	ESCALATION FACTOR
1999	389	1.878
2000	415	1.836
2001	425	1.793
2002	438	1.740
2003	441	1.728

YEAR	INDEX	ESCALATION FACTOR
2004	465	1.639
2005	493	1.546
2006	515	1.480
2007	546	1.396
2008	596	1.279
2009	578	1.318
2010	604	1.262
2011	631	1.208
2012	645	1.181
2013	653	1.167
2014	672	1.134
2015	700	1.089
2016	714	1.067
2017	711	1.072
2018	745	1.023
2019	762 (est)	1.000

Exhibit 1: Handy Whitman Index

2.6.4 Maintenance Period

A unit must choose a rolling historical period based on calendar year. A unit may choose a 10-year or 20-year period for maintenance cost. Once a unit has chosen the historical period length, the unit must stay with that period until a significant unit configuration change. Significant unit configuration change is defined as any change to the physical unit's system that significantly affects the maintenance cost for a period greater than 10 years. Examples of a significant unit configuration may include but are not limited to:

- Flue Gas Desulfurization (FGD or scrubber)
- Activated Carbon Injection (ACI)
- Selective Catalytic NOx Reduction (SCR)
- Selective Non-Catalytic NOx Reduction (SNCR)
- Low-NOx burners
- Bag House addition

- Long-term Fuel change (greater than 10 years)
- Water injection for NOx control
- Turbine Inlet Air Cooling

A maintenance period choice may also be given in circumstances of change in ownership necessitating a new Interconnection Service Agreement (ISA). Change of ownership within the same holding company is not eligible to change the historical maintenance period.

Note:

Total Maintenance Dollars must be calculated for the same historical period as Equivalent Service Hours.

2.6.5 Incremental Adjustment Parameter

Incremental Adjustment Parameter is defined as any variable cost incurred in the production of energy for PJM dispatch that is not included in the CDS guidelines for Total Fuel Related Costs or Maintenance Adder. This includes any variable cost that has been previously approved pursuant to Cost Methodology and Approval Process for inclusion. These records shall be made available to PJM and MMU upon request.

2.6.6 Equivalent Hourly Maintenance Cost

- The hourly Maintenance Cost in dollars per hour. This is defined as total maintenance dollars divided by equivalent service hours or total fuel, depending on unit type.

$$\text{EquivalentHourlyMaintenance } (\$/ \text{ Hour}) =$$

$$\frac{\text{TotalMaintenanceDollars}}{\text{EquivalentServiceHours}}$$

Or

$$\text{EquivalentHourlyMaintenance } (\$/ \text{ MBTU}) = \frac{\text{TotalMaintenanceDollars}}{\text{TotalFuel}}$$

- Estimated Year 2011 Total Maintenance Cost calculation example for a CT:

$$\text{TotalMaintenanceCost}_{2011} =$$

$$\begin{aligned} & \left(\text{AnnualMaintenanceCost}_{2010} * \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2010}} \right) + \\ & \left(\text{AnnualMaintenanceCost}_{2009} * \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2009}} \right) + \\ & \left(\text{AnnualMaintenanceCost}_{2008} * \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2008}} \right) + \\ & \dots + \left(\text{AnnualMaintenanceCost}_{2000} * \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2000}} \right) \end{aligned}$$

- Estimated Year 2011 Equivalent Service Hours calculation example:

$$\begin{aligned} \text{EquivalentServiceHours} = \\ (\text{CyclicStartingFactor} * \text{NumberOfStarts}) + \text{TotalOperatingHours} + \\ (\text{CyclicPeakingFactor} * \text{NumberOfHoursAboveBaseload}) \end{aligned}$$

Note:

Cyclic Starting Factors and Cyclic Peaking Factors values shall be consistently used for equivalent service hours and cost based offer calculations for CC and CT Units. See cyclic starting factor and cyclic peaking factor in sections 5.6.3 & 6.6.3.

$$\begin{aligned} \text{EquivalentHourlyMaintenanceCost} (\$ / \text{Hour}) = \\ \frac{\text{TotalMaintenanceDollars}}{\text{EquivalentServiceHours}} \end{aligned}$$

For Example:

$$\frac{\$406,236}{118,348 \text{ hours}} = \$3.43 / \text{Hour}$$

Exhibit 2: Example Calculation of Maintenance Adder for CT using a 10 year Maintenance Period

2.6.7 Immature Units: Maintenance Costs

Immature Units - Units with neither 10 years of operation nor 50,000 Operating Hours.

Immature Units should use actual available costs.

When a resource has less than one calendar year of operating history available, the Market Seller may use the Variable Operations and Maintenance value for its resource class published by Monitoring Analytics in the latest Annual State of the Market Report.

Once a unit reaches either 10 years of operation or 50,000 Operating Hours, it is considered a mature unit. Once a unit is mature, it will use actual historical maintenance cost and the Market Seller will decide to use a 10 or 20 year history (See section 2.6.2). If a mature unit has less maintenance history than its elected historical period, the Market Seller will use all available history to calculate the Maintenance Adder.

2.7 Synchronized Reserve

Synchronized Reserve is the capability that can be converted fully into energy within 10 minutes or customer load that can be removed from the system within 10 minutes of the request from the PJM dispatcher, and must be provided by equipment electrically synchronized to the system.

Market Sellers that request and receive reimbursement from PJM for the costs associated with operating a generating unit in the condensing mode or for altering the output of a generator at the request of PJM in order to provide Synchronized Reserves must maintain records to document how those costs were calculated. These records shall be made available to PJM upon request.

2.8 Regulation Service

Regulation is the capability of a specific resource with appropriate telecommunications, control and response capability to increase or decrease its output in response to a regulating control signal to control for frequency deviations

The cost-based regulation offer is split into two portions:

- The Regulation Capability portion consists of the fuel cost increase and unit specific heat rate degradation due to operating at lower loads and the margin risk adder;
- The Regulation Performance portion consists of the cost increase in VOM, cost increase due to heat rate increase during non-steady state operation and, where applicable, energy losses for energy storage devices. The \$/MW value determined in the performance offer will be converted to cost per mileage \$/ΔMW by dividing the value by the mileage ΔMW/MW for the applicable signal for that offer as described in Manual 11.
- Regulation Capability costs to provide Regulation Service from a unit shall include the following components up to but not exceeding:

$$\text{RegulationCapabilityCosts} (\$/MWh) \leq$$

(Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at Lower Loads)
+ Margin Risk Adder

- Regulation Performance costs to provide Regulation Service from a unit shall include the following components up to but not exceeding:

$$\text{Regulation Performance Costs} \left(\frac{\$}{\Delta MW} \right) \leq$$

{Cost Increase in VOM + Cost Increase due to Heat Rate Increase during nonsteady state operation (above heat rate factor not to exceed 0.35%) + (Energy Storage Unit Losses)} / \Delta MW / MW

Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at lower loads

The costs (in \$/MWh of Regulation) to provide Regulation Service from units shall not exceed the fuel cost increase due to operating the unit at lower loads than at the optimal economic dispatch level load and the unit specific heat rate degradation from operating at lower loads, resulting from operating the unit at lower MW output incurred from the provision of Regulation over the entire generator MW range of providing Regulation Service.

Cost Increase due to Heat Rate increase during non-steady state

The cost (in \$/MWh of Regulation) increase due to the heat rate increase resulting from operating the unit at a non-steady-state condition. This heat rate loss factor rate shall not exceed 0.35% of the top Regulation load MW heat rate value.

Margin/Risk Adder

Margin Risk Adder shall not exceed \$12.00 per MWh of Regulation Service provided.

Energy Storage Unit Losses

Energy storage unit losses can only be greater than zero for energy storage type devices and calculated in accordance with the guidance provided in section 11.8.

Cost increase in VOM

The cost increase (in \$/MWh of Regulation) of variable operations and maintenance (VOM) cost resulting from operating the unit at lower MW output incurred from the provision of Regulation. VOM costs shall be calculated by the following methods and shall not exceed those levels below:

For any unit that does not have a PJM approved Maintenance Adder, the following variable operation and maintenance (VOM) costs can be applied by unit type to the following:

Unit Type	VOM
Super-critical Steam:	\$10.00 per MWh of Regulation
Sub-critical Steam:	\$3.50 per MWh of Regulation
Combined Cycle:	\$2.50 per MWh of Regulation
Combustion Turbine:	\$2.00 per MWh of Regulation
Hydro:	\$1.00 per MWh of Regulation
Energy Storage:	Based on OEM estimates initially and actual as history is available

Exhibit 3: VOM for all Hydro Units or Non-Hydro Units providing service for less than 10 years

Any unit that has a PJM approved Maintenance Adder can use the VOM rates above if the annual VOM dollar amounts resulting from those rates included in Regulation cost based offers, are subtracted from the escalated 10 or 20 year historical total VOM accounts and the Regulation MWh based on the average of the last three years.

Energy storage units that participate only in regulation Service shall include all their VOM Cost increase in VOM adder in Regulation cost offers.

For example, a 100 MW sub-critical coal fired steam unit that has been providing Regulation Service for 30 years. The unit averaged 5,000 MWh of Regulation Service over the last three years and the escalated 20 year historical total VOM = \$10,000,000.

Annual VOM Costs to Subtract
= (\$3.50 per Regulation MWh * 5,000 MWh) * 20 years
= \$17,500 per year * 20 years
= \$350,000
20-year balance of historical total VOM accounts
= \$10,000,000 - \$350,000

Annual VOM Costs to Subtract
= \$ 9,650,000

Exhibit 4: Example of VOM for Non-Hydro Units providing Regulation for more than 10 years

Actual Regulation VOM incremental costs submitted and evaluated pursuant to the Cost Methodology and Approval Process.

For Example for a Sub-critical Coal-Fired Steam Unit providing Regulation Service for the last seven years:

Data Submitted by Participant	Value	Units
Fuel	\$1.50	\$/MMBtu
Heat Rate @ EcoMax	9,000.00	MMBtu/KWh
Heat Rate @ RegMin	12,5000.00	MMBtu/KWh
VOM	\$3.50	\$/MW of Regulation
EcoMax	100.0	MW
RegMin	40.0	MW
Unit Reg Band	10.0	MW
Margin Adder	\$12.00	\$/MW of Regulation

Heat Rate Adjustment (Operating Range)	Value	Units
Unit Base Load Heat Rate Fuel Input	360.0	MMBtu/Hr
Unit Reduced Load Heat Rate Fuel Input	500.0	MMBtu/Hr
Difference	140.0	MMBtu/Hr

$$\begin{aligned}
 & \text{UnitBaseLoadHeatRateFuelInput} = \\
 & \text{UnitBaseLoadHeatRate} * \text{RegMin} * 1\text{MMBtu} / 1,000,000 \text{ MMBtu} * 1,000 \text{ kW} / \text{MW} \\
 & \text{UnitBaseLoadHeatRateFuelInput} = \\
 & 9,000 \text{ MMBtu} / \text{kWh} * 40 \text{ MW} * 1\text{MMBtu} / 1,000,000\text{MMBtu} * 1,000 \text{ kW} / \text{MW} = 360 \text{ MMBtu} / \text{Hr} \\
 & \text{UnitReducedLoadHeatRateFuelInput} = \\
 & \text{UnitReducedLoadHeatRate} * \text{RegMin} * 1\text{MMBtu} / 1,000,000\text{MMBtu} * 1,000 \text{ kW} / \text{MW}
 \end{aligned}$$

$$\text{UnitReducedLoadHeatRateFuelInput} =$$

$$12,500\text{MMBtu} / \text{kWh} * 40 \text{ MW} * 1\text{MMBtu} / 1,000,000\text{MMBtu} * 1,000\text{kW} / \text{MW} = 500 \text{ MMBtu} / \text{Hr}$$

$$\text{Difference} = \text{UnitBaseLoadHeatInput} - \text{UnitReducedLoadHeatInput}$$

$$\text{Difference} = 500\text{MMBtu} / \text{Hr} - 360\text{MMBtu} / \text{Hr} = 140\text{MMBtu} / \text{Hr}$$

Heat Rate Adjustment (Non-Steady State Operation)	Value	Units
Total Operating Point Heat Rate	9,000.0	MMBtu/kWh
Heat Rate Loss Factor (Max per M15)	0.35%	
Heat Rate Loss	3.15	MMBtu/Hr

$$\text{HeatRateLoss} =$$

$$(\text{EconomicMaximumHeatRate} * 0.35\%) * 1\text{MMBtu} / 1,000,000\text{MMBtu} * 1,000\text{kW} / \text{MW} * \text{EconomicMaximumMW}$$

$$\text{Heat Rate Loss} =$$

$$(9,000\text{MMBtu} / \text{kWh} * 0.35\%) * 1\text{MMBtu} / 1,000,000\text{MMBtu} * 1,000\text{kW} / \text{MW} = 3.15 \text{ MMBtu} / \text{Hr}$$

(a) Heat Rate Adjustment (Operating Range)	Value	Units
Fuel Cost Adder – Operating Range	\$3.50	\$/Hr/MW of Regulation

$$\text{FuelCostAdder} =$$

$$(\text{Difference} * \text{FuelCost}) / (\text{EconomicMaximumMW} - \text{RegulationMinimumMW})$$

For Example:

$$\text{FuelCostAdder} =$$

$$(140 \text{ MMBtu} / \text{Hr} * \$1.50 / \text{MMBtu}) / (100\text{MW} - 40\text{MW}) = \$3.50 / \text{Hr} / \text{MW}$$

(b) Margin Risk Adder	Value	Units
Margin/Risk Adder	\$12.00	\$/Hr/MW of Regulation

Maximum Capability Offer	Value	Units
Heat Rate Adjustment(Operating Range) + Margin Adder	15.5	\$/Hr/MW of Regulation

Historic Mileage	Value
RegA	5

** This value is an example substitute for the average value for RegA.

(c) Heat Rate Adjustment (Non Steady-State Operation)	Value	Units
Fuel Cost Adder – Non Steady-State Operation	\$0.50	\$/Hr/MW of Regulation

$$FuelCostAdder = (HeatRateLoss * FuelCost) / RegulationBandMW$$

For Example:

$$FuelCostAdder = (3.15 \text{ MMBtu} / \text{Hr} * \$1.50 / \text{MMBtu}) / 10\text{MW} = \$0.50 / \text{Hr} / \text{MW}$$

(d) VOM Adder	Value	Units
Regulation VOM Adder	\$3.50	\$/Hr/MW of Regulation

Maximum Performance Offer	Value	Units
(c+d)/Historic Mileage	\$0.80	\$/ΔMW

$$MaximumPerformanceOffer =$$

$$[FuelCostAdder (NonSteadyStateOperation) + RegulationVOMAdder] / HistoricMileage$$

Regulation Maximum Allowable Cost Adder Example:

$$FuelCostAdder =$$

$$[\$0.50 / \text{Hr} / \text{MW} + \$3.50 / \text{Hr} / \text{MW}] / 5 \Delta \text{MW} / \text{MW} = \$0.80 / \text{Hr} / \text{MW of Regulation}$$

Exhibit 5: Regulation Maximum Allowable Cost Adder Example

Section 3: Nuclear Unit Cost Guidelines

This section presents information relevant for cost development for nuclear units.

Nuclear Plant – A facility that is licensed to produce commercial power from controlled nuclear reactions to heat water to produce steam that drives steam turbines generators.

3.1 Nuclear Heat Rate

Note:

The information in Section 2.1 contains basic Heat Rate information relevant for all unit types including nuclear units.

3.2 Performance Factor

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types including nuclear units.

3.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following information only pertains to nuclear units.

3.3.1 Basic Nuclear Fuel Cost

Basic Nuclear Fuel Cost -Basic nuclear fuel cost shall be based on the dollars in FERC Account 518, less in-service interest charges (whether related to fuel that is leased or capitalized). This quantity shall be calculated in units of dollars per MMBtu, as forecast for the applicable fuel cycle.

$$\text{BasicNuclearFuelCost } (\$/\text{MMBtu}) = \text{Dollars in FERC Account 518} - \text{InterestCost}$$

See definition in FERC account 518 in Attachment A, A2.5

3.3.2 Total Fuel-Related Costs for Nuclear Units

$$\text{TotalFuelRelatedCostsforNuclearUnits} = \text{BasicNuclearFuelCost} + \text{MaintenanceAdder}$$

3.4 Start-up Costs

Note:

The information in Section 2.4 contains basic Start-up Cost information relevant for all unit types. The following information only pertains to nuclear units.

Start-up Cost – The dollars per start as determined from start fuel, Total Fuel-Related Cost, Performance Factor, electrical costs, start maintenance adder, and additional labor cost, if required above normal station manning levels.

Start Fuel – Fuel consumed from first fire of start process (initial reactor criticality for nuclear units) to breaker closing and fuel expended from breaker opening of the previous shutdown to initialization of the (hot) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.

3.4.1 Hot Start-up Cost

Hot Start-up Cost is the expected cost to start a steam unit, which is in the "hot" condition. Hot conditions vary unit by unit, but in general, a unit is hot after an overnight shutdown. Components of hot start cost include:

- Total Fuel-Related Cost from first fire of start process (initial reactor criticality for nuclear units) to breaker closing priced at the cost of fuel currently in effect
- And shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to initialization of the (hot) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.

3.4.2 Intermediate Start-up Cost

Intermediate Start-up Cost is the expected cost to start a steam unit during a period where neither hot or cold conditions apply. Use of intermediate start cost is optional based on Market Seller's policy and physical machine characteristics. The only restriction is that once an intermediate Start-up Cost is defined for a unit, the cost must be used consistently in scheduling and accounting. Components of intermediate Start-up Cost include:

- Total Fuel-Related Cost from first fire (initial reactor criticality for nuclear units) to breaker closing priced at the cost of fuel currently in effect
- And shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to initialization of the (intermediate) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.

3.4.3 Cold Start-up Cost

Cold Start-up Cost is the expected cost to start a steam unit that is in the "cold" condition. Cold conditions vary unit by unit, but in general, a unit is cold after a two or three-day shutdown. Components of cold Start-up Cost include:

- Total Fuel-Related Cost from first fire (initial reactor criticality for nuclear units) to breaker closing priced at the cost of fuel currently in effect
- And shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to shutdown of equipment needed for normal cool down of plant components, excluding normal plant heating/auxiliary equipment fuel requirements.

3.4.4 Additional Components Applied to Hot, Intermediate and Cold Start-up Costs

These additional components for station service, labor and maintenance apply to all types of starts and should be added to the cost.

- Station service from initiation of start sequence to breaker closing (total station use minus normal base station use) priced at the Station Service rate.
- Station service after breaker opening during shutdown (station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use, this station service is not to include maintenance use or non-normal use) priced at the Station Service rate.
- Additional labor costs in excess of normal station manning requirements that are incurred when starting the unit.
- Start Maintenance Adder.

3.5 No-Load Cost

Note:

The information in Section 2.5 contains basic No-Load Cost information relevant for all unit types including nuclear units.

3.6 Maintenance Cost

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types including nuclear units.

Nuclear Maintenance Adder - The dollars per unit of fuel (or heat) as derived from FERC Accounts 530 and 531 for nuclear steam units. Market Sellers that use FERC Accounts must remove straight time labor when calculating the Maintenance Adder.

3.6.1 Configuration Addition Maintenance Adder

For units undergoing a significant system or unit Configuration Addition the use of an additional “Configuration Addition Maintenance Adder” may be included in the determination of the total maintenance adder. It is not intended to be used for upgrades to existing equipment

Examples of significant system or unit Configuration Additions may include but are not limited to:

- Conversion from open loop to closed loop circulation water systems

The specific system or unit configuration system change must be reviewed by PJM and the MMU for evaluation pursuant to the Cost Methodology and Approval Process prior to approving the use of a Configuration Addition Maintenance adder.

To calculate Total Maintenance Dollars for 2011, this example assumes a maintenance period of 10 years; please see section 2.6.3 for further explanation of Maintenance Periods.

$$TotalMaintenanceCost_{2011} =$$

$$\left((FERC\ 530\ \&\ FERC\ 531\text{-}StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531_{2010}) * \frac{EscalationIndex_{2011}}{EscalationIndex_{2010}} \right) + \left((FERC\ 530\ \&\ FERC\ 531\text{-}StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531_{2009}) * \frac{EscalationIndex_{2011}}{EscalationIndex_{2009}} \right)$$

$$+ \left((FERC\ 530\ \&\ FERC\ 531\text{-}StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2008} \right) * \frac{EscalationIndex_{2011}}{EscalationIndex_{2008}} \Bigg) +$$

$$\dots \left((FERC\ 530\ \&\ FERC\ 531\text{-}StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2000} \right) * \frac{EscalationIndex_{2011}}{EscalationIndex_{2000}} \Bigg)$$

This formula calculates total fuel for the maintenance period:

$$TotalFuel = Fuel_{2010} + Fuel_{2009} + Fuel_{2008} + \dots Fuel_{2000}$$

These allow for the calculation of the maintenance adder.

Example of Nuclear Unit's Formula of Maintenance Adder:

$$MaintenanceAdder_{2011} = \frac{TotalMaintenanceDollars}{TotalFuel}$$

Exhibit 6: Nuclear Unit's Sample Formula of Maintenance Adder

To calculate the Start Maintenance Adder, calculate the total Start Maintenance Cost. Please note the expenses in the maintenance adder and the expenses in the start maintenance adder are mutually exclusive.

$$TotalStartMaintenanceCost =$$

$$\left((StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2010} \times \frac{EscalationIndex_{2011}}{EscalationIndex_{2010}} \right)$$

$$+ \left((StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2009} \times \frac{EscalationIndex_{2011}}{EscalationIndex_{2009}} \right)$$

$$+ \left((StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2008} \times \frac{EscalationIndex_{2011}}{EscalationIndex_{2008}} \right) +$$

$$\dots \left((StartCosts\ in\ FERC\ 530\ \&\ FERC\ 531)_{2000} \times \frac{EscalationIndex_{2011}}{EscalationIndex_{2000}} \right)$$

This formula calculates the total number of starts:

$$TotalStarts = Starts_{2010} + Starts_{2009} + Starts_{2008} + Starts_{2000}$$

These allow for the calculation of the start maintenance adder:

$$= \frac{StartMaintenanceAdder_{2011} (\$/\ Start) \times InflationAdjustedTotalStartMaintenanceCost_{2000}}{TotalStarts_{2000}}$$

Exhibit 7: Nuclear Unit's Formula of Start Maintenance Adder

3.6.2 Calculation of the Configuration Addition Maintenance Adder:

The Configuration Addition Maintenance adder is to be calculated in the same manner as the maintenance cost adder described in this section with the exception that the Configuration

Addition Maintenance total maintenance dollars (CATMD) are only the incremental additional costs incurred because of the system or unit configuration change.

As with the current maintenance adder calculation, the adder for year (Y) uses the actual costs beginning with year (Y-1). Therefore, the first year of actual incremental additional expenses will be captured by the **CAMA** in the second year.

Following the initial year of use of the **CAMA**, each additional year's Configuration Addition Maintenance cost will be incorporated into the Configuration Addition Maintenance adder until the end of the historical maintenance cost period selected for the unit.

To calculate the Configuration Addition Maintenance Adder, calculate the solely incremental Maintenance Cost for the Configuration Change. Please note these expenses are purely incremental.

$$\begin{aligned}
 & \text{TotalConfigurationAdditionMaintenanceDollars} = \\
 & \left(\begin{array}{l} \text{Incremental(FERC 530+FERC 531-} \\ \text{StartCost FERC 530+FERC 531)}_{2010} \times \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2010}} \end{array} \right) + \\
 & \left(\begin{array}{l} \text{Incremental(FERC 530+FERC 531-} \\ \text{StartCost FERC 530+FERC 531)}_{2009} \times \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2009}} \end{array} \right) + \\
 & \left(\begin{array}{l} \text{Incremental(FERC 530+FERC 531-} \\ \text{StartCost FERC 530+FERC 531)}_{2008} \times \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2008}} \end{array} \right) + \\
 & \dots \left(\begin{array}{l} \text{Incremental(FERC 530+FERC 531-} \\ \text{StartCost FERC 530+FERC 531)}_{2000} \times \frac{\text{EscalationIndex}_{2011}}{\text{EscalationIndex}_{2000}} \end{array} \right) \\
 \\
 & \text{ConfigurationAdditionMaintenanceAdder} = \frac{\text{TotalConfigurationAdditionDollars}}{\text{TotalFuel}}
 \end{aligned}$$

Exhibit 8: Nuclear Unit's Formula of Configuration Addition Maintenance Adder

3.6.3 Reductions in Total Maintenance Costs

While it is expected that the Configuration Addition Maintenance adder will most often be used to cover step increases in maintenance costs, it is also to be used to capture step decreases in maintenance costs resulting from a significant system or unit configuration change that results in a significant reduction in maintenance costs. Any equipment that falls into disuse or is retired because of the configuration change must have its maintenance expenses removed from the historical record used to develop the maintenance adder. An example of a significant system or unit configuration change that may result in a step decrease in qualified maintenance costs includes, but is not limited to, conversion from open loop to closed loop circulation water systems.

3.7 Synchronized Reserve Cost

Note:

The information in Section 2.7 contains basic Synchronized Reserve information relevant for all unit types including nuclear units where applicable.

3.8 Regulation Cost

Note:

The information in Section 2.8 contains basic Regulation information relevant for all unit types including nuclear units where applicable.

Section 4: Fossil Steam Unit Cost Development

This section contains information pertaining to Fossil Steam Unit Cost development.

Fossil Steam Turbine plants use combusted fossil fuels to heat water and create steam that generates the dynamic pressure to turn the blades of a steam turbine generator.

Units that fire solid waste, biomass, or landfill gas solely or in conjunction with fossil fuels to heat water and create steam to drive a steam turbine generator are considered to be **Fossil Steam Turbine plants**.

4.1 Heat Rate

Note:

The information in Section 2.1 contains basic Heat Rate information relevant for all unit types including fossil steam units.

4.2 Performance Factor

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following information only pertains to fossil steam units.

Like units that can be used for calculation of Performance Factors are units having similar ratings, steam conditions, make or model and same site location.

4.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel information relevant for all unit types. The following information only pertains to fossil steam units.

Fossil fuel cost adjustments compensating for previous estimate inaccuracies should not be considered when determining the basic fossil cost component of Total Fuel Related Cost.

Fossil Other Fuel-Related Costs

The dollars in FERC Account 501 Fuel plus incremental expenses for fuel treatment and pollution control (excluding SO₂ and NO_x emission allowance costs) that were not included in FERC Account 501; minus the fuel expenses from FERC Account 151 that were charged into FERC Account 501, all divided by the fuel (heat content or quantity) shifted from FERC Account 151 into FERC Account 501.

4.3.1 Total Fuel Related Cost

Total Fuel Related Cost is the sum of the Basic Fuel Cost, applicable Other Fuel-Related Costs and the Maintenance Adder, CO₂, SO₂ and NO_x emission allowance costs.

$$\text{Total Fuel Related Cost (\$/MMBtu)} =$$

$$\text{Fuel Cost} + \text{Other Fuel Related Cost} + \text{SO}_2 \text{ Allowance Cost} + \text{CO}_2 \text{ Allowance Cost}$$

+ NOx Allowance Cost + Maintenance Adder

4.4 Start-up Cost

Note:

The information in Section 2.4 contains basic Start-up Cost information relevant for all unit types. The following information only pertains to fossil steam units.

Note:

In some instances, a Steam Unit with a Start-up plus Notification time greater than 48 hours may enter a state called "Extended Cold Start" as defined in M10, M13, M14D and the Markets Gateway User Guide. Steam units in this state, calculate the Start Cost information associated with this state in accordance with the "Cold Start Cost" Section below and enter this value into the "Cold Start Cost" field in Markets Gateway

$$\begin{aligned} \text{Start up Cost } (\$/\text{Start}) = & \\ & [\text{Start Fuel Consumed } (\text{MMBtu} / \text{Start}) * \text{TRFC } (\$/\text{MMBtu}) * \text{Performance Factor}] + \\ & [\text{Station Service } (\text{MWh}) * \text{Station Service Rate } (\$/\text{MWh})] + \text{Start Maintenance Adder} \\ & (\$/\text{Start}) + \text{Start Additional Labor } (\$/\text{Start}) \end{aligned}$$

4.4.1 Hot Start-up Cost

Hot Start-up Cost is the expected cost to start a steam unit, which is in the "hot" condition. Hot conditions vary unit by unit, but in general, a unit is hot after an overnight shutdown. Components of hot Start-up Cost include:

Total fuel-related cost are the costs from first fire of start process to breaker closing (including auxiliary boiler fuel) priced at the cost of fuel currently in effect including shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to initialization of the (hot) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.

Station Service from initiation of start sequence to breaker closing (total station use minus normal base station use) priced at the Station Service rate and station service after breaker opening during shutdown (station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use, this station service is not to include maintenance use or non-normal use) priced at the Station Service rate.

Additional labor costs in excess of normal station manning requirements that are incurred when starting the unit.

Start Maintenance Adder - Section 2.6 contains information regarding calculation of Maintenance Adder.

4.4.2 Intermediate Start-up Cost

Intermediate Start-up Cost is the expected cost to start a steam unit during a period where neither hot nor cold conditions apply. Use of intermediate Start-up Cost is optional based on company policy and physical machine characteristics. The only restriction is that once an intermediate Start-up Cost is defined for a unit, the cost must be used consistently in scheduling and accounting. Components of intermediate Start-up cost include:

Total fuel-related cost is the cost from first fire to breaker closing (including auxiliary boiler fuel) priced at the cost of fuel currently in effect, and shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to initialization of the (intermediate) unit start-up, excluding normal plant heating/auxiliary equipment fuel requirements.

Station Service from initiation of start sequence to breaker closing (total station use minus normal base station use) priced at the Station Service rate and station service after breaker opening during shutdown (station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use, this station service is not to include maintenance use or non-normal use) priced at the Station Service rate.

Additional labor costs in excess of normal station manning requirements that are incurred when starting the unit.

Start Maintenance Adder - Section 2.6 contains information for calculation of the Maintenance Adder.

4.4.3 Cold Start-up Cost

Cold Start-up Cost is the expected cost to start a steam unit that is in the "cold" condition. Cold conditions vary unit by unit, but in general, a unit is cold after a two or three-day shutdown. Components of cold Start-up Cost include:

Total fuel-related cost from first fire to breaker closing (including auxiliary boiler fuel) priced at the cost of fuel currently in effect, and shutdown fuel cost defined as the cost of fuel expended from breaker opening of the previous shutdown to shutdown of equipment needed for normal cool down of plant components, excluding normal plant heating/auxiliary equipment fuel requirements.

Station Service from initiation of start sequence to breaker closing (total station use minus normal base station use) priced at the Station Service rate and station service after breaker opening during shutdown (station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use, this station service is not to include maintenance use or non-normal uses) priced at the Station Service rate.

Additional labor costs in excess of normal station manning requirements that are incurred when starting the unit.

Start Maintenance Adder - Section 2.6 contains information for calculation of the Maintenance Adder.

4.5 No-Load Cost

Note:

The information in Section 2.5 contains basic No-Load Cost information relevant for all unit types including fossil steam units.

4.6 Maintenance Cost

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following information only pertains to fossil steam units.

Fossil Steam - Maintenance Adder - is the dollars per unit of fuel (or heat) as derived from FERC Accounts 512 and 513 for fossil steam units. Market Sellers that use FERC Accounts must remove straighttime labor when calculating the Maintenance Adder.

Note:

Total Maintenance Dollars (TMD) plus (+) Total Start Maintenance Dollars (TSD) cannot exceed Total Dollars in FERC Accounts 512 and 513 minus labor.

Calculate total Maintenance Dollars for 2011, this example assumes a maintenance period of 10 years; please see section 2.6.3 for further explanation of Maintenance Periods.

Total Configuration Addition Maintenance Dollars =

$$\begin{aligned} & \left(\text{Incremental (FERC 512 + FERC 513 - Start Cost FERC 512 + FERC 513)}_{2010} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2010}} \right) + \\ & \left(\text{Incremental (FERC 512 + FERC 513 - Start Cost FERC 512 + FERC 513)}_{2009} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2009}} \right) + \\ & \left(\text{Incremental (FERC 512 + FERC 513 - Start Cost FERC 512 + FERC 513)}_{2008} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2008}} \right) + \dots \\ & \left(\text{Incremental (FERC 512 + FERC 513 - Start Cost FERC 512 + FERC 513)}_{2000} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2000}} \right) + \end{aligned}$$

Calculate total fuel burned (heat input in MMBtu) for the maintenance period.

$$\text{Total Fuel} = \text{Fuel}_{2010} + \text{Fuel}_{2009} + \text{Fuel}_{2008} + \dots + \text{Fuel}_{2000}$$

These allow for the calculation of the maintenance adder:

$$\text{Maintenance Adder}_{2011} (\$/\text{MMBtu}) = \text{Total Maintenance Dollars} / \text{Total Fuel}$$

Exhibit 9: Fossil Steam Unit's Sample Formula of Maintenance Adder

To Calculate the Start Maintenance Adder, Calculate the total Start Maintenance Cost. Please note the expenses in the maintenance adder and the expenses in the start maintenance adder are mutually exclusive.

$$\begin{aligned}
 & \text{Total Start Maintenance Cost} = \\
 & \left(\text{Start Cost FERC 512+FERC 513} \right)_{2010} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2010}} + \\
 & \left(\text{Start Cost FERC 512+FERC 513} \right)_{2009} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2009}} + \\
 & \left(\text{Start Cost FERC 512+FERC 513} \right)_{2008} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2008}} + \dots \\
 & \left(\text{Start Cost FERC 512+FERC 513} \right)_{2000} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2000}} +
 \end{aligned}$$

This formula calculates the total number of starts:

$$\text{Total Starts} = \text{Starts}_{2010} + \text{Starts}_{2009} + \text{Starts}_{2008} + \dots + \text{Starts}_{2000}$$

These allow for the calculation of the start maintenance adder:

$$\text{Start Maintenance Adder} (\$/ \text{Start}) = \frac{\text{Total Start Maintenance Cost}}{\text{Total Starts}}$$

Exhibit 10: Fossil Steam Unit's Sample Formula of Start Maintenance Adder

4.6.1 Configuration Addition Maintenance Adder

For units undergoing a significant system or unit Configuration Addition the use of an additional "Configuration Addition Maintenance Adder" may be included in the determination of the total maintenance adder. It is not intended to be used for upgrades to existing equipment (i.e.: replacement of a standard burner with a low NO_x burner).

Examples of significant system or unit Configuration Additions may include but are not limited to:

- Installation of Flue Gas Desulfurization (FGD or scrubber) systems
- Activated Carbon Injection (ACI) or other sorbent injection systems
- Installation of SCR or SNCR NO_x removal systems
- Conversion from open loop to closed loop circulation water systems
- Bag House addition
- Water injection for NO_x control
- Turbine Inlet Air Cooling

The specific system or unit configuration system change needs to be reviewed by PJM and the MMU pursuant to the Cost Methodology and Approval Process and receive final approval thereof prior to the use of a Configuration Addition Maintenance adder.

4.6.2 Calculation of the Configuration Addition Maintenance Adder:

The Configuration Addition Maintenance adder is to be calculated in the same manner as the maintenance cost adder described in this section with the exception that the Configuration Addition Maintenance total maintenance dollars (CATMD) are only the incremental additional costs incurred because of the system or unit configuration change.

As with the current maintenance adder calculation, the adder for year (Y) uses the actual costs beginning with year (Y-1). Therefore, the first year of actual incremental additional expenses will be captured by the **CAMA** in the second year.

Following the initial year of use of the **CAMA**, each additional year's Configuration Addition maintenance cost will be incorporated into the Configuration Addition maintenance adder until the end of the historical maintenance cost period selected for the unit.

To Calculate the Configuration Addition Maintenance Adder, Calculate the solely incremental Maintenance Cost for the Configuration Change. Please note these expenses are purely incremental and adhere to the requirements in section 3.8.1. Also note that labor must be removed from all applicable FERC Accounts.

Total Configuration Addition Maintenance Dollars =

$$\begin{aligned} & \left(\text{Incremental (FERC 512 + FERC 513- Start Cost FERC 512+FERC 513)}_{2010} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2010}} \right) + \\ & \left(\text{Incremental (FERC 512 + FERC 513- Start Cost FERC 512+FERC 513)}_{2009} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2009}} \right) + \\ & \left(\text{Incremental (FERC 512 + FERC 513- Start Cost FERC 512+FERC 513)}_{2008} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2008}} \right) + \dots \\ & \left(\text{Incremental (FERC 512 + FERC 513- Start Cost FERC 512+FERC 513)}_{2000} * \frac{\text{Escalation Index}_{2011}}{\text{Escalation Index}_{2000}} \right) \end{aligned}$$

Exhibit 11: Fossil Unit's Sample Formula of Configuration Addition Maintenance Adder

4.6.3 Reductions in Total Maintenance Costs:

While it is expected that the Configuration Addition Maintenance adder will most often be used to cover step increases in maintenance costs, it is also to be used to capture step decreases in maintenance costs resulting from a significant system or unit configuration change that results in a significant reduction in maintenance costs. Any equipment that falls into disuse or is retired because of the configuration change must have its maintenance expenses removed from the historical record used to develop the maintenance adder. An example of a significant system or unit configuration change that may result in a step decrease in qualified maintenance costs includes, but is not limited to, a fuel change from coal to gas fuel.

4.7 Synchronized Reserve

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following information only pertains to fossil steam units.

Total costs to provide Tier 2 Synchronized reserve from a steam unit shall include the following components:

$$\text{Total Costs Tier 2 Synchronized Reserve (\$/MW) =}$$

$$\frac{\text{Heart Rate Increase} * \text{Variable Cost Rate}}{\text{MW of Synchronized Reserve}} +$$

Margin (less than \$7.50) + Lost Opportunity Costs

Further information on Tier 1 and Tier 2 Synchronized Reserve can be found in [PJM Manual 11](#). Heat Rate Increase is the incremental increase resulting from operating the unit at lower MW output resulting from the provision of Synchronized reserve service

Total Steam Unit offers must be expressed in dollars per hour per MW of Synchronized Reserve (\$/MWh) and must specify the total MW of Synchronized Reserve offered.

For Example:

	Output	Heat Rate
Steam Unit Full Load:	100 MW	9,000 MMBtu/kWh
Steam Unit Reduced Load:	70 MW	9,500 MMBtu/kWh
VOM Rate:	\$0.50/MMBtu	
Heat Rate Penalty =	$(9,500 - 9,000)/9,000 = 5.56\%$	
Adjusted VOM =	$\$0.50 * 1.0556 = \$0.5278/\text{MMBtu}$	
Steam Unit Reduced Load Heat Input =	$9,500 * 70 / 1000 = 665 \text{ MMBtu/Hr}$	
Heat Rate VOM Penalty =	$(\$0.5278/\text{MMBtu} - \$0.50/\text{MMBtu}) * 665 \text{ MMBtu/Hr} = \$18.487/\text{Hr}$	
Synchronized Reserve VOM Adder =	$\$18.487/\text{Hr} / (100 \text{ MW} - 70 \text{ MW}) = \$0.6162/\text{Synchronized MW}$	

Exhibit 12: Steam Unit Synchronized Reserve Example

4.8 Regulation

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types including fossil steam units.

Section 5: Combined Cycle (CC) Cost Development

This section contains information pertaining to CC Cost development.

Combined Cycle - An electric generating technology in which electricity is generated by both a CT generator (the Brayton Cycle) and a steam turbine generator (the Rankine Cycle) hence the name CC. The CT exhaust heat flows to a conventional boiler or to a heat recovery steam generator (HRSG) to produce steam for use by a steam turbine generator in the production of electricity.

Heat recovery steam generator (HRSG) – A CT exhaust feeds hot gas into a heat to steam exchanger installed on combined-cycle power plants designed to utilize the heat in the CT exhaust to produce steam to drive a conventional steam turbine generator.

5.1 Heat Rate

Note:

The information in Section 2.1 contains basic Heat Rate information relevant for all unit types including CC.

5.2 Performance Factors

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types including CC units.

5.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types including CC units.

5.4 Start-up Cost

Note:

The information in Section 2.4 contains basic Start-up Cost information relevant for all unit types. The following additional information only pertains to CC units.

Start-up Costs for Combined Cycle (CC) plants shall include only the following components and shall never be less than zero:

TFRC = Total Fuel Related Cost

$$\begin{aligned} \text{Start up Cost (\$/ Start)} = & \\ & (\text{Start Fuel Consumed (MMBtu/ Start)} * \text{TFRC}(\$/ \text{MMBtu}) * \text{Performance Factor}) \\ & + (\text{Station Service (MWh)} * \text{Station Service Rate} (\$/ \text{MWh})) \end{aligned}$$

+ *Start Maintenance Adder (\$/ Start)*+ *Start Incremental Labor Cost (\$/ Start)*

Start Fuel Consumed Cost is the cost of start fuel (basic fuel cost plus fuel handling and other fuel-related costs) from first CT fire to breaker closing for the steam turbine generator, as measured during a normal start sequence, and the cost of shutdown fuel from last breaker opening to fuel valve closure. Additionally, this includes the cost of start fuel from CT first fire to the point where heat recovery steam generator (HRSG) steam pressure matches steam turbine inlet pressure, for any CT unit/HRSG combinations started after synchronization of the steam turbine generator.

Station Service is included from initiation of start sequence of initial CT to breaker closing of the steam turbine generator (total station use minus normal base station use) priced at the Station Service Rate.

Add to this (+) station service after breaker opening of the last component when finished operating as a CC unit, priced at the Station Service rate. (Station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use. This station service is not to include maintenance use or non-normal uses.)

Minus (-) the integration of net generation from CT synchronization to steam turbine generator synchronization or to HRSG steam output at line pressure, priced at the actual cost of the unit.

Minus (-) the integration of net generation during the shutdown period, priced at the actual cost of the unit.

Incremental labor costs in excess of normal station manning requirements (only when necessary to start the CC unit).

Start Maintenance Adder. This quantity includes both the previously defined CT Starting Maintenance Cost

5.5 No-Load Cost

Note:

The information in Section 2.5 contains basic Start-up Cost information relevant for all unit types including CC units.

5.6 Maintenance Cost

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to CC units.

Combined Cycle Maintenance Adder – The dollars per unit of fuel (or heat) as derived from actual maintenance expenses or FERC Accounts 512, 513, and 553. If submitting as a simple cycle CT, use actual maintenance expenses or total dollars from FERC Account 553 divided by Equivalent Service Hours (ESH). Market Sellers that use FERC Accounts must remove straight time labor when calculating the Maintenance Adder.

5.6.1 Combined Cycle / CT Long Term Service Agreement Cost Recovery

A Market Seller that has a currently in effect Long Term Service Contract (LTSA) with a third party vendor to provide overhaul and maintenance work on a CT either as part of a CC plant or as a stand-alone CT, may file with PJM and the MMU for inclusion of any variable long term maintenance costs in cost based offer bids pursuant to the Cost Methodology and Approval Process, if the following conditions are met:

- The included variable long-term maintenance costs are consistent with the definition of such costs in the Cost Development Guidelines
- And the dollar value of each component of the variable long-term maintenance costs is set specifically in the LTSA.
- Costs are specified on either an operating hour or number of starts basis.

5.6.2 Long Term Maintenance Expenses

Long Term Maintenance Expenses - CC Plant major inspection and overhaul expenses can be included in the calculation of a combustion turbine's or diesel engine's maintenance adder if they were not included in the unit's capacity offer for a Delivery Year in which the unit cleared a Base Residual or Incremental Auction.

5.6.3 Equivalent service hours (ESH)

The estimated hours the unit will run based on history:

$$\begin{aligned} \text{Equivalent Service Hours} = & \\ & (\text{Cyclic Starting Factor} * \text{Number of Starts}) + \\ & \text{Total Operating Hours at any load level} + \\ & (\text{Cyclic Peaking Factor} * \text{Number of Hours above Base load temperature limit}) \end{aligned}$$

CC CTs shall use OEM supplied values for Cyclic starting factors and Cyclic peaking factors even if the CT technology is no longer being built. In situations where cyclic starting factors or Cyclic peaking factors are unknown or unavailable, CC CTs shall use:

Cyclic starting factor = 5.0 for aircraft - type CTs and 10.0 for industrial - type CTs

And

Cyclic peaking factor = 3.0 for all CTs.

Where

A Cyclic starting factor = 10.0 for an industrial – type CT

For example, the incremental maintenance charged to one start on an industrial - type CT is equivalent to the incremental maintenance attributable to ten hours of base load operation.

And the Cyclic peaking factor = 3.0

means that the additional incremental maintenance charged to the incremental energy between base and peak loads is equivalent to the incremental maintenance attributable to three hours of base load operation.

5.7 Synchronized Reserve

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following information only pertains to CC units.

Total costs to provide Synchronized reserve from a CC unit shall include the following components:

$$\begin{aligned} \text{Total Costs Synchronized Reserve (\$/MW)} = & \\ & \frac{\text{Heat Rate Increase} * \text{Variable Cost Rate}}{\text{MW of Synchronized Reserve}} + \\ & \text{Margin (less than \$7.50) + Lost Opportunity Costs} \end{aligned}$$

Heat Rate Increase is the incremental increase resulting from operating the unit at lower MW output resulting from the provision of Synchronized reserve service

Total CC Unit offers must be expressed in dollars per hour per MW of Synchronized Reserve (\$/MWh) and must specify the total MW of Synchronized Reserve offered.

For Example:

	Output	Heat Rate
CC Unit Full Load:	450 MW	7,500 MMBtu/kWh
CC Unit Reduced Load:	400 MW	7,800 MMBtu/kWh
VOM Rate:	\$0.50/MMBtu	
Heat Rate Penalty =	$(7,800 - 7,500) / 7,500 = 4\%$	
Adjusted VOM =	$\$0.50 * 1.04 = \$0.52/\text{MMBtu}$	
CC Unit Reduced Load Heat Input =	$7,800 * 400 / 1000 = 3,120 \text{ MMBtu/Hr}$	
Heat Rate VOM Penalty =	$(\$0.52/\text{MMBtu} - \$0.50/\text{MMBtu}) * 3,120 \text{ MMBtu/Hr} = \$62.40/\text{Hr}$	
Synchronized Reserve VOM Adder =	$\$62.40/\text{Hr} / (450 \text{ MW} - 400 \text{ MW}) = \$1.248/\text{Synchronized MW}$	

Exhibit 13: Combined Cycle Unit Synchronized Reserve Example

5.8 Regulation

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types including CC units.

Section 6: Combustion Turbine (CT) and Diesel Engine Costs

This section details specific information for the cost development of units that are CTs or diesel engines.

Combustion Turbine Unit – A generating unit in which a natural gas or oil fired CT engine is the prime mover for an electrical generator. CTs that fire landfill gas solely or in conjunction with fossil fuels as a prime mover for an electrical generator are considered to be a Combustion Turbine Unit.

Diesel Engine – A generating unit in which a diesel reciprocating engine is the prime mover for an electrical generator. Reciprocating engines that fire landfill gas solely or in conjunction with fossil fuels as a prime mover for an electrical generator are considered to be a Diesel Engine.

6.1 Combustion Turbine and Diesel Engine Heat Rate

Note:

The information in Section 2.1 contains basic Heat Rate information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

For CT generating units, no-load fuel shall be the theoretical or actual fuel burn rate expressed in MMBtu/Hr at the point of electric bus synchronization.

6.2 Performance Factor

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

‘Like’ CT Units - An average Performance Factor may be calculated and applied for groups of like units burning the same type of fuel. Like includes same primary manufacturer not necessarily engine or generator manufacturer, but one with overall system responsibility. The following are two examples:

- Worthington sells CT's with P&W engines and a GE generator. Worthington would be considered the primary manufacturer.
- Same general frame size - a manufacturer may modify a basic design to produce units with varying capabilities. Units built with such variations may be placed in a may be placed in a single group.

6.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

CT Maintenance Adder is included directly with the individual operating cost components on a \$/hour basis.

6.3.1 Combustion Turbine other Fuel-Related Costs

The dollars in FERC Account 547, plus incremental expenses for fuel treatment and pollution control excluding SO₂ and NO_x emission allowance costs that were not included in Account 547; minus the fuel expenses from FERC Account 151 that were charged into Account 547, all divided by the fuel (heat content or quantity) shifted from Account 151 into Account 547.

6.3.2 Total Fuel Related Cost (TFRC) Equation for CTs

$$\begin{aligned} \text{Total Fuel Related Costs for Combustion Turbines} = \\ \text{Basic Fossil Fuel Cost} + \text{Other Fuel Related Cost} + \\ \text{SO}_2 \text{ emission costs} + \text{NO}_x \text{ emission costs} + \text{CO}_2 \text{ emission costs} \end{aligned}$$

Note:

CT Maintenance Adder is included directly in start, no-load and peak segment components.

6.4 Start-up Cost

Note:

The information in Section 2.4 contains basic Start-up Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

Start-up costs for all CTs and diesel units shall include only the following components:

$$\begin{aligned} \text{Start up Cost} \left(\frac{\$}{\text{Start}} \right) \\ = (\text{Start Fuel Consumed (MMBtu / Start)} * \text{TFRC} (\$ / \text{MMBtu}) * \text{Performance Factor}) \\ + (\text{Station Service (MWh)} * \text{Station Service Rate} (\$ / \text{MWh})) \\ + \text{Start Maintenance Adder} (\$ / \text{Start}) + \text{Start Incremental Labor Cost} (\$ / \text{Start}) \end{aligned}$$

Start Fuel Consumed * Total Fuel Related Cost (TFRC) * Performance Factor is the cost of start fuel (basic fuel cost plus fuel handling and other fuel-related costs) from first fire to unit breaker closing, Plus (+) cost of shutdown fuel from unit breaker opening to fuel valve closure (basic fuel cost plus fuel handling and other fuel-related costs).

Incremental labor costs are the costs in excess of normal station manning requirements (only when necessary to start a CT unit).

Station Service * Station Service Rate from initiation of start sequence to breaker closing (total station use minus normal base station use) priced at the Station Service rate. Plus (+) station service after breaker opening during shutdown (station service during shutdown should be that associated with the normal unit auxiliary equipment operated during shutdown in excess of base unit use, this station service is not to include maintenance use or non-normal uses) priced at the Station Service rate.

Note:

Starting Maintenance Cost, please see section 6.6.3

Reminder: CT Maintenance Adder is included directly in start, no-load and peak segment components.

6.5 No-Load Cost Calculation for CTs

Note:

The information in Section 2.5 contains basic No-Load Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

Note:

CT Maintenance Adder is included directly in start, No-Load and peak segment components.

6.6 Maintenance Cost

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

CT - Maintenance Adder – The total dollars from actual maintenance expenses or FERC Account 553 divided by Equivalent Service Hours (ESH), MWh, or per unit of fuel (or heat). Market Sellers that use FERC Accounts must remove straight time labor when calculating the Maintenance Adder.

Industrial CT – This is a CT developed specifically for power generation.

Aircraft - Type CT – These are CTs originally designed for aircraft and modified for power generation.

Diesel - Maintenance Adder – The total dollars from FERC Account 553 divided by total fuel burned (in MMBtu's).

Combustion Turbine Start – For calculating CT maintenance cost, only the number of successful starts to synchronization shall be used. Successful starts should include those at the direction of PJM and for company tests.

Long Term Maintenance Expenses – CT Plant major inspection and overhaul expenses can be included in the calculation of a combustion turbine's or diesel engine's maintenance adder if they were not included in the unit's capacity offer for a Delivery Year in which the unit cleared a Base Residual or Incremental Auction.

6.6.1 Combustion Turbine Maintenance Adder Example

$$\text{Equivalent Hour Maintenance Cost} = \frac{\text{Total Maintenance Dollars}}{\text{Equivalent Service Hours}}$$

(Industrial Unit)

Peak Hours = 200 Hrs

Service Hours = 2000 Hrs
No. of Starts = 300
Peak Pickup = 5 MW

Peak Hours are the hours run above base load temperature rating.

Total Maintenance Dollars = \$100,000

(Actual historical maintenance data escalated to present value).

Cyclic starting factor = 10, Cyclic peaking factor = 3 (Note: Cyclic starting factor = 5 for aircraft engine CT's).

Equivalent Hourly Maintenance Cost (EHMC) =

$$\frac{\$100,000}{(10*300)+2,000+(3*200)} = \frac{\$17.86}{Hr}$$

Calculation of maintenance rates

Starting Maintenance Cost

*= Cyclic Starting Factor * Equivalent Hourly Maintenance Cost*

*= 10 * \$17.86 = \$178.60 per start*

Hourly Maintenance Rate = Equivalent Hourly Maintenance Cost = \$17.86 / hour

Peak Incremental Maintenance Rate =

$$\frac{\text{Cyclic Peaking Factor}}{\text{Peak Pickup}} *$$

$$\text{Equivalent Hourly Maintenance Cost} = \frac{3 * \$17.86}{5} = \$10.72 \text{ per MWh}$$

Exhibit 14: Combustion Turbine Maintenance Cost Adder Example

6.6.2 Combustion Turbine Long Term Service Agreement Cost Recovery

A Market Seller that has a currently effective LTSA with a third party vendor to provide overhaul and maintenance work on a CT may file a request to PJM and the MMU for inclusion of any variable long term maintenance costs in cost based offer bids, pursuant to the Cost Methodology and Approval Process if the following conditions are met:

- The included variable long-term maintenance costs are consistent with the definition of such costs in the Cost Development Guidelines
- And the dollar value of each component of the variable long-term maintenance costs is set specifically in the LTSA.
- Costs are specified on either an operating hour or number of starts basis.

6.6.3 Equivalent service hours

The estimated hours the unit will run based on history.

$$\begin{aligned} \text{Equivalent Service Hours} = & \\ & (\text{Cyclic Starting Factor} * \text{Number of Starts}) \\ & + \text{Total Operating Hours at any load level} \\ & + (\text{Cyclic Peaking Factor} * \text{Total Operating Hours above base load temperature limit}) \end{aligned}$$

CTs shall use OEM supplied values for cyclic starting factors and cyclic peaking factors even if the CT technology is no longer being built. In situations where cyclic starting factors or cyclic peaking factors are unknown or unavailable, CTs shall use:

cyclic starting factor = 5.0 for aircraft - type CTs and cyclic starting factor = 10.0 for industrial - type CTs

And

cyclic peaking factor = 3.0 for all CTs

Where:

A cyclic starting factor = 10.0 for an industrial - type CTs

for example, the incremental maintenance charged to one start on an industrial - type CT is equivalent to the incremental maintenance attributable to ten hours of base load operation.

And a cyclic peaking factor = 3.0

means that the additional incremental maintenance charged to the incremental energy between base and peak loads is equivalent to the incremental maintenance attributable to three hours of base load operation.

6.6.4 Diesel Incremental Maintenance Adder Calculation

The incremental Maintenance Adder for diesel units will be calculated and applied on a "per MMBtu (or other unit of fuel)" basis. The calculation will be based on actual operation and escalated maintenance expenses for all available history in the Maintenance Period.

6.7 Synchronized Reserve: Costs to Condense

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

Total synchronous condensing costs for CTs and diesel units shall include the following components:

- **Start-up Costs** if applicable, shall be applied when a unit moves from cold to condensing operations and when a unit moves from condensing operations to energy generation, but shall not be applied when a unit moves from energy generation to condensing operations.

- **Variable Operating and Maintenance cost (EHMC)** in \$/Hr divided by the Synchronized MW provided.
- **Actual cost of power consumed during condensing operations** at real time bus LMP as determined by Market Settlements. MW consumed must be included in the offer.
- **Margin** up to \$7.50 per MW of Synchronized Reserve service provided.

The CT condensing offers must be expressed in dollars per hour per MW of Synchronized Reserve (\$/MWh) and must specify the total MW of Synchronized Reserve offered.

6.8 Regulation Cost

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types. The following additional information only pertains to CT and diesel engine units.

Section 7: Hydro

This section contains information for the development of Hydro or Pumped Storage Hydro cost offers.

Hydro Units – Generating unit in which the energy of flowing water drives the turbine generator to produce electricity. This classification includes pumped and run-of-river hydro.

Pumped Storage Hydro Unit – Hydroelectric power generation that stores energy in the form of water by pumping from a lower elevation source to a higher elevation reservoir, then allowing the upper reservoir to drain turning the turbines to produce power.

7.1 Pumping Efficiency (Pumped Storage Hydro Only)

Pumping Efficiency is the Pumped Storage Hydro Unit's version of a heat rate. It measures the ratio of generation produced to the amount of generation used as fuel.

Pumping Efficiency (PE) is calculated by dividing the MWh of generation produced while operating in generation mode by the MWh required to pump the water needed to produce the generation MWh.

$$\text{Pumping Efficiency} = \frac{\text{MWh Generation Produced}}{\text{MWh Generation Pumped as Fuel}}$$

For example, it requires 1,000 ft³ to produce one MWh of generation as water flows from the pond to the sink and it requires 1.4 MWh of pumping load to pump 1,000 ft³ of water from the sink to the pond. The resultant efficiency is:

$$\text{Pumping Efficiency} = \frac{\text{MWh Generation Produced}}{\text{MWh Generation Pumped as Fuel}} = \frac{3.5 \text{ MWh (Generated)}}{5 \text{ MWh (Pumped)}} = 0.70$$

In order to account for environmental and physical factors associated with the characteristics of the pond and pumping operations that limit the accuracy of calculating short term pumping efficiency, a seven day rolling total of pumping and generation MWh are utilized for pumping efficiency calculations.

PE can be calculated by one of three methods. A Market Seller must make the choice of method by December 31 prior to the year of operation and cannot change to another method for a period of one calendar year.

- Option 1: Twelve month calendar actual Pumping Efficiency.
 - o The previous 12-month calendar year average Pumping Efficiency based on actual pumping operations.
- Option 2: Three month rolling Pumping Efficiency.
 - o The previous three months rolling actual efficiency where the average monthly availability is 50% or greater. The calculation must be updated after each month.
- Option 3: The previous month actual Pumping Efficiency.
 - o The previous month actual efficiency where the availability is 50% or greater. The calculation must be updated monthly.

7.2 Performance Factors

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following additional information only pertains to hydro units.

7.3 Fuel Cost

The fuel costs for a run-of-river hydro Unit are equal to zero.

For a Pumped Storage Hydro Unit to be consistent with other PJM units within this manual the term fuel cost is used to account for the energy necessary to pump from the lower reservoir to the upper reservoir.

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following additional information only pertains to Pumped Storage Hydro Units.

If a Market Seller wishes to change its method of calculation of pumped storage TFRC, the Market Seller shall notify PJM and the MMU in writing by December 31 prior to the year of operation, to be evaluated pursuant to the Cost Methodology and Approval Process before the beginning of the cycle in which the new method is to become effective. The new cycle starts on February 1st and continues for a period of one year

Basic Pumped Storage Fuel Cost – Pumped storage fuel cost shall be calculated on a seven (7) day rolling basis by multiplying the real time bus LMP at the plant node by the actual power consumed when pumping divided by the pumping efficiency. The pumping efficiency is determined annually based on actual pumping operations or by OEM curves if annual data is not available due to the immaturity of the unit. The following equations govern pumping storage fuel cost:

$$\begin{aligned}
 & \text{Pumping Power Cost } \left(\frac{\$}{MWh} \right) = \frac{\sum_{168}^1 \text{Real Time LMP } \left(\frac{\$}{MWh} \right) * \text{Pumping Power (MWh)}}{\sum_{168}^1 \text{Pumping Power (MWh)}} \\
 & \text{Pumped Storage Fuel Cost } (\$/MWh) = \frac{\text{Pumping Power Cost } (\$/MWh)}{\text{Pumping Efficiency}}
 \end{aligned}$$

7.3.1 Total Energy Input Related Costs for Pumped Storage Hydro Plant Generation

Total energy input-related costs for all pumped storage hydro units shall be defined as follows:

$$\begin{aligned}
 & \text{Pumped Storage Hydro Total Energy Input Related Cost} \\
 & = \text{Basic Pumped Storage Energy Input Cost} + \text{Maintenance Cost}
 \end{aligned}$$

7.4 Start-up Cost

See section 7.7 Condensing Start Costs.

7.5 No-Load Cost

Hydro Units do not have No-Load Costs.

7.6 Maintenance

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to hydro units.

This account shall include the, materials used and expenses incurred in the maintenance of plant, includible in Account 332, Reservoirs, Dams, and Waterways. (See operating expense instruction 2.) However, the cost of materials used and expenses incurred in the maintenance of fish and wildlife, and recreation facilities, the book cost of which is includible in Account 332, Reservoirs, Dams, and Waterways, shall be charged to Account 545, Maintenance of Miscellaneous Hydraulic Plant. Further, Pumped Storage Hydro Units scheduled by the Office of the Interconnection pursuant to the hydro optimization tool in the Day-ahead Energy Market may not include maintenance costs in their offers because such offers may not exceed an energy offer price of \$0.00/MWh. Market Sellers that use FERC accounts must remove straight time labor expenses from the accounts as those costs are typically recovered in the capacity market.

7.7 Synchronized Reserve: Hydro Unit Costs to Condense

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following additional information only pertains to hydro units if applicable.

Some Hydro Units have the ability to purge the turbines of water and run backwards effectively creating a capacitor. This method of operation of the machine is referred to as operating the Hydro unit in synchronous condensing mode.

Total synchronous condensing costs for Hydro units shall include the following components:

$$\begin{aligned} & \text{Hydro Costs to Condense } (\$/MWh) \\ & = \text{Condensing Start Costs} + \left(\frac{VOM}{\text{Synchronized Reserve MW}} \right) + \text{Margin} \end{aligned}$$

Condensing Start costs if applicable, start costs shall be applied when a unit moves from cold to condensing operations and when a unit moves from condensing operations to energy generation, but shall not be applied when a unit moves from energy generation to condensing operations.

In addition (+) identified **variable Operating and Maintenance** cost in \$/Hr. divided by the Synchronized MW provided. These costs shall be totaled over the Maintenance Period and

divided by total MWh generated over the maintenance period. These variable Operating and Maintenance costs shall include:

- Maintenance of Electric Plant as derived from FERC Account 544
- Maintenance of Reservoirs as derived from FERC Account 543

In addition (+) **margin** up to \$7.50 per MW of Synchronized Reserve service provided.

Total hydro condensing offers must be expressed in dollars per hour per MW of Synchronized Reserve (\$/MWh) and must specify the total MW of Synchronized Reserve offered.

7.8 Regulation Cost

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types.

Section 8 : Demand Resource (DR)

Demand Resource – DR means a resource that has the capability to provide a reduction in load.

8.1 Demand Resource (DR) Cost to Provide Synchronous Reserves

The cost to provide synchronous reserves from DR resources shall be equal to the margin up to \$7.50 per MWh of reserves provided.

Demand Resource shutdown costs shall be zero.

Section 9: Wind Units

This section contains information for the development of Wind unit cost offers.

Wind Units – Generating unit in which the energy of blowing wind drives the turbine generator to produce electricity.

9.1 Heat Rates

Wind units do not burn fuel so heat rates are not applicable.

9.2 Performance Factors

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following additional information only pertains to Wind units.

Wind units do not burn fuel so Performance Factors are equal to 1.0.

9.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following additional information only pertains to wind units.

"Fuel Cost Policy" will be provided to PJM and the MMU annually pursuant to Section 2.3.1. The Fuel Cost Policy should include how the generator intends to account for Renewable Energy Credits (RECs) and Production Tax Credits (PTCs).

9.4 Start-up Cost

Note:

The information in Section 2.3 contains basic Start-up Cost information relevant for all unit types. The following additional information only pertains to wind units.

Start-up cost for a wind unit is station service cost.

9.5 No-Load Cost

Wind Units do not have No-load costs.

9.6 Maintenance

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to wind units.

Maintenance Cost includes major overhauls and inspections, as well as short run Wear and Tear on the Unit (including preventative and scheduled; not including capital). Rolling twelve-month historic maintenance cost divided by MWh for the same period.

9.7 Synchronized Reserve: Wind Unit Costs to Condense

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following additional information only pertains to wind units if applicable.

9.8 Regulation Cost

The information in section 2.8 contains basic Regulation Cost information relevant for all unit types.

Section 10: Solar Units

This section contains information for the development of solar unit cost offers.

Solar Units – Solar units use photovoltaic cell collectors made from semiconductors to convert solar radiation directly to electricity.

10.1 Heat Rates

Solar units do not burn fuel so heat rates are not applicable.

10.2 Performance Factors

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following additional information only pertains to solar units.

Solar units do not burn fuel so Performance Factors are equal to 1.0.

10.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following additional information only pertains to solar units.

Solar unit's fuel costs are equal to zero.

10.4 Start-up Cost

Note:

The information in Section 2.3 contains basic Start-up Cost information relevant for all unit types. The following additional information only pertains to solar units.

Solar unit's Start Fuel and Total Fuel Related Costs are equal to zero.

10.5 No-Load Cost

Solar units do not have No-Load Costs.

10.6 Maintenance

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to solar units.

10.7 Synchronized Reserve Cost

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types.

10.8 Regulation Cost

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types.

Section 11: Batteries and Flywheels

This section contains information for the development of battery and flywheel cost offers. .
Regulation only resources should see Section 11.8.

Battery- device to store electrical energy via chemicals

Flywheel- mechanical device for storing rotational energy

11.1 Efficiency Factor

Efficiency factor is a battery or flywheel version of a heat rate. Efficiency factors measure the ratio of generation produced to the amount of electricity used to charge.

$$\text{Efficiency Factor} = \frac{\text{MWh Discharged}}{\text{MWh Charged}}$$

Efficiency factors can be calculated over the time period specified by the Market Seller in the Fuel Cost Policy. A Market Seller must make the choice of method in their fuel cost policy and cannot change to another method for a period specified in Section 2.1

11.2 Performance Factors

Note:

The information in Section 2.2 contains basic Performance Factor information relevant for all unit types. The following additional information only pertains to batteries and flywheels.

Battery and flywheel Performance Factors are equal to 1.0.

11.3 Fuel Cost

Note:

The information in Section 2.3 contains basic Fuel Cost information relevant for all unit types. The following additional information only pertains to batteries and flywheels:

To be consistent throughout the manual, the term fuel cost is used to account for the energy necessary to charge the battery or flywheel.

11.3.1 Total Fuel Cost

Market Sellers for batteries and flywheels must identify in their Fuel Cost Policies the methodology they are using to calculate fuel cost (charging cost).

$$\text{Fuel Cost} \left(\frac{\$}{\text{MWh}} \right) = \left(\text{average charge cost} \left(\frac{\$}{\text{MWh}} \right) * \text{efficiency factor} \right)$$

11.3.2 Operating Costs

Operating Costs may include, but are not limited to: acids and lithium ion replacements

11.4 Start-up Cost

Battery and flywheel Start Fuel and Total Fuel Related Costs are equal to zero.

11.5 No-Load Cost

Battery and flywheel no-load costs are equal to zero.

11.6 Maintenance

Note:

The information in Section 2.6 contains basic Maintenance Cost information relevant for all unit types. The following additional information only pertains to batteries and flywheels.

Batteries and flywheels cannot include costs that can be included in their capacity offer such as straight time labor. Maintenance costs for batteries and flywheels may include, but are not limited to: cell repairs/replacements, inverter maintenance, and generation owned GSU/ Interconnection Transmission maintenance.

11.7 Synchronized Reserve Cost

Note:

The information in Section 2.7 contains basic Synchronized Reserve Cost information relevant for all unit types. The following additional information only pertains to batteries and flywheels if applicable.

The cost to provide synchronous reserves from battery or flywheel resources shall be equal to the margin up of \$7.50 per MWh of reserves offered plus the maintenance adder

11.8 Regulation Cost

Note:

The information in Section 2.8 contains basic Regulation Cost information relevant for all unit types. The following additional information only pertains to batteries and flywheels.

Batteries and flywheels shall calculate Energy Storage Unit Losses in accordance with the equation below. The “Cost Increase due to Heat Rate Increase during non-steady state operation” and the “Fuel Cost Increase and Unit Specific Heat Rate Degradation due to Operating at lower loads” shall be equal to zero.

If a Market Seller wishes to change its method of calculating these losses, the Market Seller shall submit a request to change its Fuel Cost Policy to PJM and the MMU pursuant to Section 2.3.1. The approved method of calculation may be implemented upon approval and may be updated no more frequently than once every 12 months. If any action by a government or regulatory agency that results in a need for the Market Seller to change its method of cost calculation, the affected Market Seller may submit a request, or notification as appropriate, to PJM and the MMU for evaluation, pursuant to Section 2.3.1.

Energy Storage Unit Losses (\$/MW) – shall be the calculated average of seven (7) days of rolling hourly periods where the real time bus LMP (\$/MWh) at the plant node is multiplied by the net energy consumed (MWh) when regulating divided by the regulation offer (MW). The seven (7) days of rolling hourly periods shall consist of the unit’s last 168 hour periods with accepted regulation offers. The following equation governs energy storage unit’s fuel cost increase:

$$\begin{aligned} & \text{Energy Storage Unit Losses } (\$/MW) \\ & = \text{Average of 7 Days} \left\{ \frac{\left(\text{Hourly LMP} \left(\frac{\$}{MWh} \right) * \text{Hourly Net Energy Consumed } (MWh) \right)}{\text{Hourly Accepted Regulation Offers } (MW)} \right\} \end{aligned}$$

Section 12: Energy Market Opportunity Cost and Non-Regulatory Opportunity Cost Guidelines

12.1 Opportunity Cost Policy

Opportunity Cost may be a component of cost under certain circumstances.

- Specific business rules for Opportunity Costs have been defined in the Operating Agreement for various products including energy and regulation.
- Requests for recovery of Opportunity Costs not defined in the Operating Agreement should be submitted to PJM and the MMU pursuant to the Cost Methodology and Approval Process.

The Opportunity Cost Calculator described in Section 12.3 through 12.6 of this manual is suspended as of June 1, 2020. Market Sellers that wish to include an Opportunity Cost in a unit's cost based offers should use the IMM Opportunity Cost Calculator described in Section 12.7 of this manual.

For details on how to obtain an opportunity cost adder from the IMM Opportunity Cost Calculator, contact the IMM at MMU_Energy_Offers_Review@monitoringanalytics.com.

For any other questions related to Opportunity Cost adders please contact PJM at FuelCostPolicyAnalysis@pjm.com.

12.2 Basis for Opportunity Cost to be included in Cost Offers

There are three reasons for the application of Opportunity Costs as contained in this section.

12.2.1 Energy Market Opportunity Costs

Energy Market Opportunity Costs associated with an externally imposed environmental run-hour restriction on a generation unit. Examples would include a limit on emissions for the unit imposed by a regulatory agency or legislation, a direct run hour restriction in the operating permit, or a heat input limitation defined by a regulatory decision or operating permit.

12.2.2 Non-Regulatory Opportunity Cost: Physical Equipment Limitations:

Physical Equipment Limitations must have supporting evidence submitted by the Market Seller. Documentation such as an OEM recommendation or bulletin and/or insurance carrier restrictions would meet this criterion. Only limitations that cause the unit to experience a restriction in the number of starts or run hours would be eligible for Non-Regulatory Opportunity Cost.

12.2.3 Non-Regulatory Opportunity Cost: Fuel Limitations

Fuel Limitations are eligible for Non-Regulatory Opportunity Costs for a fuel supply limitation, for up to one year, resulting from an event of force majeure.

Force Majeure is defined as: Any cause beyond the control of the affected Interconnection Party or Construction Party, including but not restricted to, acts of God, flood, drought, earthquake, storm, fire, lightning, epidemic, war, riot, civil disturbance or disobedience, labor dispute, labor or material shortage, sabotage, acts of public enemy, explosions, orders, regulations or restrictions

imposed by governmental, military, or lawfully established civilian authorities, which, in any of the foregoing cases, by the exercise of due diligence such party could not reasonably have been expected to avoid, and which, by the exercise of due diligence, it has been unable to overcome. Force Majeure does not include (i) a failure of performance that is due to an affected party's own negligence or intentional wrongdoing; (ii) any removable or remediable causes (other than settlement of a strike or labor dispute) which an affected party fails to remove or remedy within a reasonable time; or (iii) economic hardship of an affected party.

12.3 Calculation Method Options: Two Methodologies for calculating Opportunity Cost

Market Sellers may opt to follow one of the two following methodologies; the difference between the methodologies being the applicable time period. Market Sellers may develop alternative methods specific to their units and submit those methods for approval. Requests for recovery of opportunity costs using other methods not defined in the Operating Agreement should be submitted to PJM and the MMU for evaluation under the Cost Methodology and Approval Process and shall receive PJM's approval prior to using the alternative method

Energy Market Opportunity Costs and Non-Regulatory Opportunity Costs are a distinct component of the cost-based offer. As is the case with any computation of the cost-based offer in Manual 15, Market Sellers may elect to enter their cost-based offer at a value less than the computed cost-based offer. However, they may not exceed the computed value.

12.3.1 Long Term Method (greater than 30 days)

This method uses monthly forward prices as the basis for forecasts of fuel and electricity costs in the future. Opportunity costs calculated with this method will change frequently. Given that electricity and fuel futures can change daily, the opportunity costs computed can likewise change daily. Market Sellers who include opportunity costs in their cost-based offers must recalculate their long-term opportunity cost no less frequently than once per every 7 days.

12.3.2 Short Term Method (30 days or less)

This method uses daily forward prices as the basis for forecasts of fuel and electricity costs in the future. Market Sellers who include opportunity costs in their cost-based offers must recalculate their short term opportunity cost every day.

12.4 Definitions

VALUE	DEFINITION
N	number of hours in the month (on-peak/off-peak)
Y	Year
m	month
d	day of the month

VALUE	DEFINITION
h	hour
t	Number of hours remaining in the compliance period
Peak	off-peak hours only or on-peak hours only
FY	future year
BUSLMP	LMP at the unit's bus
PJMWHLMP	PJM Western Hub LMP
PJMWHFRP	PJM Western Hub Forward Price
DAPJMWHFRP	Day Ahead PJM Western Hub Forward Price
Trading Day	In respect of a particular futures market a day on which that Market open for trading
Dm	Delivery Month; Month the commodity contract is to deliver the commodity in the future.
Base year	one of the three historical years used to create volatility in the fuel and power forecasts
Peak	Peak hours are from 7:00 AM to 11:00 PM (the hour ending 0800 to the hour ending 2300) prevailing local time. Peak days are Mondays through Fridays, excluding North American Electric Reliability Corporation (NERC) holidays.
Off-peak	Off-peak hours are from midnight to 7:00 AM (the hour ending 0100 to the hour ending 0700) and 11:00 PM to midnight (the hour ending 2400) Mondays through Fridays; also, all day Saturdays and Sundays (the hour ending 0100 to the hour ending 2400) and North American Electric Reliability Corporation holidays
Frequently mitigated unit (FMU)	A unit that was offer-capped for more than a defined proportion of its real-time run hours in the most recent 12-month period. FMU thresholds are 60 percent, 70 percent and 80 percent of run hours. Such units are permitted a defined adder to their cost-based offers in place of the usual 10 percent adder.
Unit Cost	Cost of Dispatch without Start-up Cost
Unit Dispatch Cost	Cost of Dispatch with Start-up Cost Included

All inputs use prevailing width preserving decimal precision of historical record.

12.5 Long Term Methodology

12.5.1 Step 1: Derive Historical Monthly LMP Basis Differential between the generation bus and western hub

Inputs required for STEP 1: Platts-ICE Forward Curve for “PJM west” from the recent trading day, Three years of historical hourly real-time LMPs at the generation bus, and Three years of historical hourly real-time PJM Western Hub LMPs

The mismatch between the location of the forward contract delivery point (Western Hub) and the relevant generator bus can be accounted for in the historic, monthly average basis differential for both peak and off-peak hours. This basis differential can be expressed as the average, over all peak or off-peak hours in a month, of the ratio of the hourly bus LMP to the hourly Western Hub LMP. If this ratio is greater than one, it means the bus LMP is greater than the Western Hub LMP on average. If this ratio is less than one, it means the bus LMP is less than the Western Hub LMP on average.

Platts-ICE Forward Curve for “PJM west” (PJM Western Hub) must be collected for this first step (<http://www.platts.com/>). These PJM Western Hub Forwards multiplied by a historical basis adjustment ratio for delivery to the generator’s bus creates monthly delivered bus prices. The three prior calendar year’s historical data is used to make this calculation. For example, when calculating opportunity costs for July 2, 2010 for a unit with a calendar year compliance period, use historical LMP data from July 2nd (2007,2008,2009) to December 31st (2007,2008,2009). The Opportunity Cost Calculator is also able to provide forecasts for a rolling compliance period (e.g. a rolling 12 months) rather than a calendar year period. For units with a 12 month rolling compliance period, use LMP data from the previous three years, beginning on the date calculated and ending two days previous. For example, when a unit is calculating opportunity cost for July 2nd, 2010 with a rolling 12 month compliance period, use historical LMP data from July 2nd (2007,2008,2009) to June 30th (2008, 2009, 2010). Begin by taking the hourly bus prices for the three prior calendar years at the generator’s bus, and for every hour, divide that hour’s price by the corresponding price at PJM Western Hub. The historic hourly basis differential in hour h, day d, month m, and year y is:

$$\text{HourlyBasisDifferentialRatio}_{y,m,d,h} = \frac{\text{BUSLMP}_{y,m,d,h}}{\text{PJMWHLMP}_{y,m,d,h}}$$

Note:

When PJMWHLMP is zero and the BUSLMP is zero, then the ratio value is one. If PJMWHLMP is zero and the BUSLMP is not zero then value is null and it is not included in the average.

$$\text{HourlyBasisDifferentialRatio}_{\text{June 3, 2007 H11}} = \frac{\text{BUSLMP}_{\text{June 3, 2007 H11}}}{\text{PJMWHLMP}_{\text{June 3, 2007 H11}}}$$

$$\text{HourlyBasisDifferentialRatio}_{\text{June 3, 2008 H11}} = \frac{\text{BUSLMP}_{\text{June 3, 2008 H11}}}{\text{PJMWHLMP}_{\text{June 3, 2008 H11}}}$$

$$\text{HourlyBasisDifferentialRatio}_{\text{June 3, 2009 H11}} = \frac{\text{BUSLMP}_{\text{June 3, 2009 H11}}}{\text{PJMWHLMP}_{\text{June 3, 2009 H11}}}$$

Exhibit 15: Three hourly basis differential ratios variables for the same hour in each of three historical years

Once the hourly basis ratios are calculated for every hour during the three-year history, for each historic month take the sum of the on-peak hourly basis differentials in the month, and divide by the number of peak hours in the month (observations). Similarly, for every month, sum the off-peak hourly basis ratios, and then divide by the number of off-peak hours within that month. When calculating the monthly peak basis ratio all days in the month will be used for the average. These monthly basis differentials adjust PJM Western Hub monthly peak and off-peak forward prices to expected peak and off-peak monthly forward prices delivered to the generator's bus.

$$\begin{aligned} \text{MonthlyPeakBasisDifferentialRatio}_{y, m}^{\text{peak}} &= \frac{\sum_{\text{peak hours}} * (\text{HourlyBasisDifferentialRatios}_{y, m, d, h}^{\text{peak}})}{\text{Number of Peak Hours in month } m} \\ \text{MonthlyOffPeakDifferentialRatio}_{y, m}^{\text{peak}} &= \frac{\sum_{\text{peak hours}} * (\text{HourlyBasisDifferentialRatios}_{y, m, d, h}^{\text{off-peak}})}{\text{Number of Off-Peak Hours in month } m} \\ \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2007}}^{\text{peak}} &= \frac{\sum_{\text{peak hours}} * (\text{HourlyBasisDifferentialRatios in June 2007})}{\text{Number of Peak Hours in June 2007}} \\ \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2008}}^{\text{peak}} &= \frac{\sum_{\text{peak hours}} * (\text{HourlyBasisDifferentialRatios in June 2008})}{\text{Number of Peak Hours in June 2008}} \\ \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2009}}^{\text{peak}} &= \frac{\sum_{\text{peak hours}} * (\text{HourlyBasisDifferentialRatios in June 2009})}{\text{Number of Peak Hours in June 2009}} \end{aligned}$$

Exhibit 16: Monthly Peak Basis Differentials for the three historical periods

Multiply monthly peak and off-peak basis differential ratios by the respective monthly peak and off-peak PJM Western hub forwards to derive forecasted monthly peak and off-peak bus prices from the historical year. When calculating the monthly peak basis differential ratio all days in the month will be used for the average.

$$\text{Forecasted Monthly Bus Price}_{fy, m}^{peak} * [\text{PJMWesternHub}_{fy, m}^{peak} * \text{MonthlyPeakBasisRatio}_{y, m}^{peak}]$$

$$\begin{aligned} & \text{ForecastedMonthlyBusPrice}_{June\ 2010, base\ 2007}^{OFFpeak} \\ & = \\ & [(\text{PJMWHFRP}_{for\ delivery\ June\ 2010}^{OFFpeak}) \end{aligned}$$

$$\begin{aligned} & \text{ForecastedMonthlyBusPrice}_{June\ 2010, base\ 2008}^{OFFpeak} \\ & = \\ & [(\text{PJMWHFRP}_{for\ delivery\ June\ 2010}^{OFFpeak}) \end{aligned}$$

$$\begin{aligned} & \text{ForecastedMonthlyBusPrice}_{June\ 2010, base\ 2009}^{OFFpeak} \\ & = \\ & [(\text{PJMWHFRP}_{for\ delivery\ June\ 2010}^{OFFpeak}) \end{aligned}$$

Exhibit 17: Forecasted monthly bus prices for three historical periods

Outputs required for STEP 1: Three peak and off-peak monthly BUS LMP forecasts for each month remaining in the compliance period.

12.5.2 Step 2: Derive hourly volatility scalars to incorporate hourly volatility into the LMP forecast

Inputs required for STEP 2: Three years of historical hourly real-time LMPs at the generation bus

The monthly futures prices quoted only consider the average peak and off-peak prices for the month and do not consider hourly LMP volatility. Step 2 derives will develop an hourly volatility scalar. This scalar will later be multiplied against the forecast in Step 1 to derive an hourly

bus LMP forecast that incorporates historic hourly peak and off-peak LMP volatility as well as monthly peak and off-peak basis differentials from the historical year with PJM Western Hub.

First, for each historic month compute the average peak and off-peak price at the unit's bus for each remaining month in the compliance period. When calculating the monthly average bus LMP all days in the month will be used for the average.

$$\text{MonthlyAverageBusLMP}_{y,m}^{\text{peak}} = \frac{\sum_{\text{peak hours}} (\text{HourlyBusLMP}_{y,m,d,h}^{\text{peak}})}{\text{Number of Peak Hours in month } m}$$

$$\text{MonthlyAverageBusLMP}_{y,m}^{\text{off-peak}} = \frac{\sum_{\text{off-peak hours}} (\text{HourlyBusLMP}_{y,m,d,h}^{\text{off-peak}})}{\text{Number of Off-Peak Hours in month } m}$$

Next, for every hour, take the hourly bus LMP divided by the relevant monthly average peak or off-peak bus LMP computed above. If the hour is an on-peak hour, divide by the average peak LMP for the month.

$$\text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{peak}} = \frac{\text{BUSLMP}_{y,m,d,h}^{\text{peak}}}{\text{MonthlyAverageBusLMP}_{y,m}^{\text{peak}}}$$

If the hour is off-peak, divide that hour by the monthly off-peak average price for the corresponding month.

$$\text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{off-peak}} = \frac{\text{BUSLMP}_{y,m,d,h}^{\text{off-peak}}}{\text{MonthlyAverageBusLMP}_{y,m}^{\text{off-peak}}}$$

Example 2.1: Volatility scalar for the each of the three historical years:

$$\text{HourlyVolatilityScalar}_{\text{June3,2007 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2007 H23}}}{\text{Average Offpeak June 2007 BUSLMP}}$$

$$\text{HourlyVolatilityScalar}_{\text{June3,2008 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2008 H23}}}{\text{Average Offpeak June 2008 BUSLMP}}$$

$$\text{HourlyVolatilityScalar}_{\text{June3,2009 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2009 H23}}}{\text{Average Offpeak June 2009 BUSLMP}}$$

Outputs from STEP 2: Three ratio values per hour for each of the historical years used for volatility.

12.5.3 Step 3: Create three sets of hourly forecasted bus values

Inputs to STEP 3: Output from STEP 1: On-peak/off-peak monthly bus LMP Forecast Output from STEP 2: Hourly volatility scalars

Step 3 creates three hourly forecasts from the volatility scalars developed in step 2 and the monthly bus LMP forecasts developed in Step 1. Multiply the hourly volatility scalars developed in step 2 by the corresponding peak or off-peak from the historical year forecasted monthly bus price calculated in Step 1.

The expected or forecasted LMP for hour h, day d, month m, based on year y that is a peak hour is:

$$\text{ForecastedBUSLMP}_{y,m,d,h}^{\text{peak}} = \text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{peak}} * \text{ForecastedMonthlyBusPrice}_{f,y,m}^{\text{peak}}$$

The expected or forecasted LMP for hour h, day d, month m, based on year y that is an off-peak hour is:

$$\text{ForecastedBUSLMP}_{y,m,d,h}^{\text{off-peak}} = \text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{off-peak}} * \text{ForecastedMonthlyBusPrice}_{f,y,m}^{\text{off-peak}}$$

Assume that it is April 5, 2010. To create the set of three forecasted prices for each hour of June 3, 2010:

$$\begin{aligned} \text{ForecastedBUSLMP}_{\text{June 3, 2010 H23, base 2007}} &= \text{HourlyVolatilityScalar}_{\text{June 3, 2007 H23}} * \text{ForecastedMonthlyBusPrice}_{\text{June 2010}}^{\text{off peak}} \\ \text{ForecastedBUSLMP}_{\text{June 3, 2010 H23, base 2008}} &= \text{HourlyVolatilityScalar}_{\text{June 3, 2008 H23}} * \text{ForecastedMonthlyBusPrice}_{\text{June 2010}}^{\text{off peak}} \\ \text{ForecastedBUSLMP}_{\text{June 3, 2010 H23, base 2009}} &= \text{HourlyVolatilityScalar}_{\text{June 3, 2009 H23}} * \text{ForecastedMonthlyBusPrice}_{\text{June 2010}}^{\text{off peak}} \end{aligned}$$

Exhibit 18: Forecasted bus LMPs for one hour for each of the three historical base years

Outputs from STEP 3: Three hourly bus LMP forecasts for each hour remaining in the compliance period

12.5.4 Step 4: Create a daily fuel volatility scalar

Inputs to STEP 4: Three years historical hourly daily fuel prices at the generator bus (\$/MMBtu) Fuel Weights if dual fuel

Step 4 creates a daily fuel volatility scalar using historic daily delivered fuel prices (as used to develop a unit's TFRC) from the previous three calendar years. Take each daily bus-delivered fuel price and divide it by the monthly average bus delivered fuel price to create a ratio for every day in the three-year history. In calculating monthly average bus price, all days in the month will be used for the average. For units that have dual fuels; the daily delivered fuel prices need to be multiplied by their respective weights and then added together. N_m is the number of days in month m.

Units with Single Fuel Type:

$$\text{DailyFuelVolatilityScalar}_{y,m,d} = \frac{\text{DeliveredFuelPrice}_{y,m,d}}{\frac{(\sum_{r=1}^{N_m} (\text{DeliveredFuelPrice}_{y,m}))}{N_m}}$$

Units with Dual Fuel:

$$\text{DailyFuelVolatilityScalar}_{y,m,d} = \frac{\left((\text{DeliveredFuelPriceFuelTypeA}_{y,m,d} * \text{WeightFuelTypeA}) + (\text{DeliveredFuelPriceFuelTypeB}_{y,m,d} * \text{WeightFuelTypeB}) \right)}{\frac{\sum_{r=1}^{N_m} \left((\text{DeliveredFuelPriceA}_{y,m} * \text{WeightA}) + (\text{DeliveredFuelPriceB}_{y,m} * \text{WeightB}) \right)}{N_m}}$$

$$\text{DailyFuelVolatilityScalar}_{\text{June},3,2007} = \frac{\text{DeliveredFuelPrice}_{\text{June } 3,2007}}{\text{Average June 2007 DeliveredFuelPrice}}$$

$$\text{DailyFuelVolatilityScalar}_{\text{June},3,2008} = \frac{\text{DeliveredFuelPrice}_{\text{June } 3,2008}}{\text{Average June 2008 DeliveredFuelPrice}}$$

$$\text{DailyFuelVolatilityScalar}_{\text{June},3,2009} = \frac{\text{DeliveredFuelPrice}_{\text{June } 3,2009}}{\text{Average June 2009 DeliveredFuelPrice}}$$

Exhibit 19: Three daily fuel volatility scalars values developed for June 3 in each of three historic years for a unit with a single fuel

If there is not fuel cost record for a given date, use the pervious available date.

Outputs from STEP 4: Three years of historic daily scalars for fuel volatility

12.5.5 Step 5: Create three daily delivered fuel forecasts

Inputs for STEP 5: Platts Forward Curve for Fuels from the most recent trading day, for delivery in the compliance period (\$/MMBtu) with a daily delivery charge adjustment Fuel Weights if dual fuel Fuel Contract monthly prices, if applicable Output from STEP 4: Three historic years daily scalars for fuel volatility

Step 5 takes fuel futures and/or contract prices and the daily delivered fuel scalars from step 4 and multiplies them to create a fuel forecast that corresponds on an average monthly basis to the fuel futures, yet maintains historical volatility. For units that have dual fuels, the fuel forwards for the two fuels will be multiplied by their respective weights (derived from expected use of each fuel), added together, and then multiplied by the daily fuel volatility scalar. For units with some or all of their fuel procured by contract, the contract and fuel forwards are multiplied by

their respective weights (derived from expected use of each fuel) and added together and then multiplied by the daily fuel volatility scalar. The current daily delivery charge adjustment will be applied through the compliance period.

Unit with a single fuel:

$$\begin{aligned}
 & \text{DailyDeliveredFuel}_{fy,m,d} = \\
 & \text{DailyFuelVolatilityScalar}_{y,m,d} * \\
 & [((\text{WeightSpot}_m * \text{FuelForward}_{fy,m}) + (\text{WeightContract} * \text{ContractPrice}))]
 \end{aligned}$$

Where $\text{WeightContract}_m + \text{WeightContract}_m = 1$

Unit with dual fuel:

Permits the use of dual fuels for units that may burn multiple fuels or source fuels from different areas at different prices. For units with restrictions on consumption of specific fuels, this method allows accounting for both fuels in the same calculation.)

$$\begin{aligned}
 & \text{DailyDeliveredFuel}_{fy,m,d} = \\
 & \text{DailyFuelVariabilityScalar}_{y,m,d} * [\text{WeightFuelTypeA}_m \\
 & * (\text{WeightContractFuelTypeA}_m * \text{ContractPriceFuelTypeA}_m \\
 & + \text{WeightSpotFuelTypeA}_m * (\text{DeliveryAdjustmentFuelTypeA} \\
 & + \text{FuelForwardFuelTypeA}_{fy,m})) + \text{WeightFuelTypeB}_m * (\text{WeightContractFuelTypeB}_m \\
 & * \text{ContractPriceFuelTypeB}_m + \text{WeightSpotFuelTypeB}_m \\
 & * (\text{DeliveryAdjustmentFuelTypeB} + \text{FuelForwardFuelTypeB}_{fy,m}))] \\
 & \text{Where } \text{WeightFuelTypeA}_m + \text{WeightFuelTypeB}_m = 1 \\
 & \text{Where } \text{WeightContractFuelTypeA}_m + \text{WeightSpotFuelTypeA}_m = 1 \\
 & \text{Where } \text{WeightContractFuelTypeB}_m + \text{WeightSpotFuelTypeB}_m = 1
 \end{aligned}$$

Unit with a single fuel:

$$\begin{aligned}
 & \text{DailyDeliveredFuelForecast}_{\text{June 3, 2009, base 2007}}^{\text{base 2007}} = \text{DailyFuelVolatilityScalar}_{\text{June 3, 2007}} * \text{FuelForward}_{\text{June 2010}} \\
 & \text{DailyDeliveredFuelForecast}_{\text{June 3, 2009, base 2008}}^{\text{base 2008}} = \text{DailyFuelVolatilityScalar}_{\text{June 3, 2008}} * \text{FuelForward}_{\text{June 2010}} \\
 & \text{DailyDeliveredFuelForecast}_{\text{June 3, 2009, base 2009}}^{\text{base 2009}} = \text{DailyFuelVolatilityScalar}_{\text{June 3, 2009}} * \text{FuelForward}_{\text{June 2010}}
 \end{aligned}$$

Exhibit 20: Create three daily delivered fuel forecasts from the volatilities of three historic years

Outputs from STEP 5: Daily generator-bus delivered fuel forecast

12.5.6 Step 6: Create generating unit(s) cost for each of the three forecasts

Inputs for STEP 6: Expected future full load seasonal (May-September/October-April) heat rate for the compliance period Fuel Prices output from STEP 5 Unit SO₂, CO₂ and NO_x Emission Rates (lbs/MMBtu) – Futures prices for SO₂, CO₂ and NO_x from Evolution Markets (\$/ton) modified to \$/lb Maintenance Adder, VOM and FMU, as defined in Manual 15

In step 6, take the unit characteristics, future emission allowance prices, the three daily fuel forecasts and create a daily unit cost for the three forecasts using the appropriate heat rate for the forecast day. Unit costs do not include Start-up Costs will be added later in the calculation of Unit Dispatch Cost. For each day in the three fuel forecasts, a unit dispatch cost is calculated as follows:

$$\text{Unit Cost}_{fy,m,d}^{\text{base year}} =$$

$$\left\{ \left[\text{UnitHeatRate} \left(\frac{\text{MMBtu}}{\text{mwh}} \right) * \text{DailyDeliveredFuelForecast} \left(\frac{\$}{\text{MMBtu}} \right)_{\text{Future year,m,d}}^{\text{base year}} \right] + \right.$$

$$\left[\text{UnitHeatRate} \left(\frac{\text{MMBtu}}{\text{mwh}} \right) * \text{UnitNOxEmissionRate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of NO}_x \left(\frac{\$}{\text{lb}} \right) \right] +$$

$$\left[\text{UnitHeatRate} \left(\frac{\text{MMBtu}}{\text{mwh}} \right) * \text{UnitSO}_2\text{EmissionRate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of SO}_2 \left(\frac{\$}{\text{lb}} \right) \right] +$$

$$\left[\text{UnitHeatRate} \left(\frac{\text{MMBtu}}{\text{mwh}} \right) * \text{UnitCO}_2\text{EmissionRate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of CO}_2 \left(\frac{\$}{\text{lb}} \right) \right] + \text{VOM} + \} \text{either a } \left\{ \begin{array}{l} 10\% \text{ margin} \\ \text{OR FMU adder} \end{array} \right.$$

Unit Heat Rate 10.35 MMBtu/MWH
 Unit NO_x Emission Rate 0.328 lbs/MMBtu
 Unit SO₂ Emission Rate 1.2 lbs/MMBtu
 Unit CO₂ Emission Rate 117 lbs/MMBtu
 DailyDeliveredFuelForecast \$5.56/MMBtu
 Combined NO_x Allowance cost \$1375/ton
 SO₂ Allowance cost \$200/ton
 CO₂ emission cost \$8.00/ton
 VOM & Maintenance Adder \$2.22/MWh
 FMU \$0.00/MWh

$$\begin{aligned}
 \text{UnitCost} &= \left[\left(\frac{10.35\text{MMBtu}}{\text{mwh}} \right) * \left(\frac{\$5.56}{\text{MMBtu}} \right) \right] \\
 &+ \left[\left(\frac{10.35\text{MMBtu}}{\text{mwh}} \right) * \left(\frac{0.328 \text{ lbs}}{\text{MMBtu}} \right) * \left(\frac{\$1375.00}{\text{ton}} \right) * \left(\frac{\text{ton}}{2000 \text{ lbs}} \right) \right] \\
 &+ \left[\left(\frac{10.35\text{MMBtu}}{\text{mwh}} \right) * \left(\frac{1.2 \text{ lbs}}{\text{MMBtu}} \right) * \left(\frac{\$200.00}{\text{ton}} \right) * \left(\frac{\text{ton}}{2000 \text{ lbs}} \right) \right] \\
 &+ \left[\left(\frac{10.35\text{MMBtu}}{\text{mwh}} \right) * \left(\frac{117 \text{ lbs}}{\text{MMBtu}} \right) * \left(\frac{\$8.00}{\text{ton}} \right) * \left(\frac{\text{ton}}{2000 \text{ lbs}} \right) \right] + \left(\frac{\$2.22}{\text{MWh}} \right) + \left(\frac{\$0}{\text{MWh}} \right) \\
 \text{UnitCost}_{f,y,m,d}^{\text{base year}} &= \left(\frac{\$58.58}{\text{MWh}} \right) + \left(\frac{\$2.33}{\text{MWh}} \right) + \left(\frac{\$1.24}{\text{MWh}} \right) + \left(\frac{\$4.84}{\text{MWh}} \right) + \left(\frac{\$2.22}{\text{MWh}} \right) = \$69.21 / \text{MWh}
 \end{aligned}$$

Exhibit 21: Daily Unit Cost

Outputs for STEP 6: Three forecasts based on historic year factors for daily generator unit cost

12.5.7 Step 7: Calculate the margin for every hour in the three hourly forecasts

Inputs for STEP 7: Daily Generator Unit Cost from STEP 6 Hourly Generator bus LMP forecast from STEP 3 All future maintenance outage information Unit-specific minimum runtime parameter restriction Unit-specific Start-up costs (cold Start-up Costs for CC and CT units and hot Start-up Costs for steam units) Unit economic maximum

Step 7 calculates the hourly margin the generator would receive by comparing the cost offer developed in step 6 against the hourly forecasted bus LMPs developed in step 3. To remove planned outages, for any future date that the unit will be offline, set the outage hours to unavailable for all three forecasts.

For Units with minimum run time restrictions, this step calculates the total margins in blocks of adjacent hours, based on the sum of the margins of each block and the minimum runtime parameter restriction of the unit. Blocks may include additional incremental hours, if these hours are found to be more valuable than the additional block, up to double the unit's minimum runtime. Adjacent hour blocks with equal or greater number of hours than double a unit's minimum run time will be split into multiple blocks (however, adjacent blocks do not use an additional Start-up Cost). For units with Start-up Costs, the value of the unit's Start-up Cost divided by economic maximum will be subtracted from the total margin of each block that contains a new start, but not from each subsequent incremental hour added to the block, in order to correctly value hours that do not incur Start-up Costs. Calculate the total margins for all blocks of hours in the three forecasts.

$$\begin{aligned}
 \text{TotalMarginBlock}_{t=\text{block}+\text{MRT}-1}^{\text{base year}} &= \sum_{t=\text{block}}^{\text{block}} \left(\text{ForecastedBusLMP}_{y(t),m(t),d(t),h(t)}^{\text{base year}} - \text{UnitDispatchCost}_{\text{future } y,m,d}^{\text{base year}} \right)
 \end{aligned}$$

**MRT = Minimum Run Time

*** Unit Dispatch Cost include Start-up cost when applicable

Where the block ranges from one to

$[total\ number\ of\ hours - min\ run\ time + 1]$ and $y(t)$, $m(t)$, $d(t)$, $h(t)$ are the year, month, day and hour corresponding to the t^{th} overall hour of the time period spanning from the date calculated to the end of the compliance period forecasted.

The **totalNumberOfHours** Total Number of Hours variable represents the number of hours left in the compliance period to be forecasted, and is based on the date calculated and whether or not the unit has a rolling 12 month run-hour restriction.

This example uses block # 3788:

$$\begin{aligned}
 & TotalMarginBlock_{block\ 3788}^{2007} \\
 = & \sum_{t=block}^{t=block+MRT-1} (ForecastedBusLMP_{y(t),m(t),d(t),h(t)}^{base\ year} - UnitDispatchCost_{future\ year}^{base\ year}) \\
 = & \sum_{t=3788}^{t=3788+1-1} (ForecastedBusLMP_{y,m,d,h(t)}^{2007} - UnitDispatchCost_{y,m,d(t)}^{2007}) \\
 = & ForecastedBusLMP_{y,m,d,h\ (3788)}^{2007} - UnitDispatchCost_{y,m,d,h\ (3788)}^{2007} \\
 = & ForecastedBusLMP_{June\ 3,\ 2010\ H07}^{2007} - UnitDispatchCost_{June\ 3,\ 2010}^{2007} = \$78.27 - \$69.21 = \$9.06
 \end{aligned}$$

Similarly,

$$\begin{aligned}
 & TotalMarginBlock_{block\ 3788}^{2008} \\
 = & ForecastedBusLMP_{June\ 3,\ 2010\ H07}^{2008} - UnitDispatchCost_{June\ 3,\ 2010}^{2008} \\
 = & \$58.00 - \$52.41 = \$5.59
 \end{aligned}$$

And,

$$\begin{aligned}
 & TotalMarginBlock_{block\ 3788}^{2009} \\
 = & ForecastedBusLMP_{June\ 3,\ 2010\ H07}^{2009} - UnitDispatchCost_{June\ 3,\ 2010}^{2009} \\
 = & \$63.78 - \$76.72 = -\$12.94
 \end{aligned}$$

Exhibit 22: Calculating total margins with a minimum runtime of one hour (i.e. no minimum runtime restriction), using historical data from the past three calendar years

At this point, the blocks of hours would be ranked according to the value of their total margins.

Outputs from STEP 7: Three sets of ranked blocks of total margin forecasts including each hour in the compliance period, adjusted to include Start-up Costs for

each block that contains a new start, with all future outage hours removed.

12.5.8 Step 8: Determine the opportunity cost component

Inputs to STEP 8: *Three sets of ranked blocks of total margin forecasts*

For each of the three years, the opportunity cost component for that year will be the average total margin of the lowest value block added before the run hour limit was reached. The three opportunity costs will then be averaged to get the opportunity cost component available to the generator. If the final opportunity cost component is less than zero then the opportunity cost component will be set to zero.

The average value of the block which includes the
 $700^{\text{th}} \text{ hour}_{\text{base } 2007} = \$7.99 / \text{MWh}$

The average value of the block which includes the
 $700^{\text{th}} \text{ hour}_{\text{base } 2008} = \$ - 2.54 / \text{MWh}$

The average value of the block which includes the
 $700^{\text{th}} \text{ hour}_{\text{base } 2009} = \$10.59 / \text{MWh}$

$$700^{\text{th}} \text{ hour opportunity cost component} = \frac{\$7.99 + (-\$2.54) + \$10.59}{3} = \$5.33 / \text{MWh}$$

Exhibit 23: A unit with 700 run hours

Outputs from STEP 8: *Maximum Opportunity Cost Component that can be included in an environmentally run limited generator's cost offer*

12.6 Short Term Methodology

Short Term Opportunity Costs are of limited duration where the event lasts 30 days or less. The Short Term Method modifies the method in Section 12.5 to capture intra-month price movements in fuel and electricity markets on a daily basis. The proposal requires Market Sellers to recalculate opportunity costs every day during the short-term episode, using daily forward prices for both fuel and electricity costs instead of monthly forwards.

12.6.1 Step 1: Derive Historical Monthly LMP Basis Differential between the generation bus and western hub

Inputs required for STEP 1: Platts-ICE Forward Curve for “PJM west” from the recent trading day, Three years of historical hourly real-time LMPs at the generation bus, and Three years of historical hourly real-time PJM Western Hub LMPs

As before with Opportunity Costs, PJM Western Hub (Western Hub) is a liquid trading point for forward LMP prices. The mismatch between the location of the forward contract delivery point Western Hub and the relevant generator bus can be accounted for in the historic monthly average basis differential for peak and off-peak hours. The basis differential is an average for the peak or off-peak hours intra-month of the hourly bus LMP to the hourly Western Hub LMP. The result is a ratio of the bus to the hub by time. If this ratio is greater than one, it means the bus LMP is greater than the Western Hub LMP. If this ratio is less than one, it means the bus LMP is less than the Western Hub LMP on average. The resultant ratio can be applied to the PJM Western Hub to shape it into the specific generator bus.

Platts-ICE Forward Curve for “PJM west” (PJM Western Hub) must be collected for this first step (<http://www.platts.com/>). The PJM Western Hub daily forward prices are multiplied by the historical basis adjustment ratio or shaping factor at the generator’s bus to approximate the intra-month delivered bus prices.

Begin by taking the hourly intra-month bus prices for the three prior calendar years at the generator’s bus, and for every hour, divide that hour’s price by the corresponding price at PJM Western Hub. The historic hourly basis differential in hour h, day d, month m, and year y is:

$$\text{HourlyBasisDifferentialRatio}_{y,m,d,h} = \text{BUSLMP}_{y,m,d,h} / \text{PJMWHLMP}_{y,m,d,h}$$

Note:

When PJMWHLMP is zero and the BUSLMP is zero, then the ratio value is one. If PJMWHLMP is zero and the BUSLMP is not zero then value is null and it is not included in the average.

$$\text{HourlyBasisDifferentialRatio}_{\text{June } 3, 2007 \text{ H11}} = \frac{\text{BUSLMP}_{\text{June } 3, 2007 \text{ H11}}}{\text{PJMWHLMP}_{\text{June } 3, 2007 \text{ H11}}}$$

$$\text{HourlyBasisDifferentialRatio}_{\text{June } 3, 2008 \text{ H11}} = \frac{\text{BUSLMP}_{\text{June } 3, 2008 \text{ H11}}}{\text{PJMWHLMP}_{\text{June } 3, 2008 \text{ H11}}}$$

$$\text{HourlyBasisDifferentialRatio}_{\text{June } 3, 2009 \text{ H11}} = \frac{\text{BUSLMP}_{\text{June } 3, 2009 \text{ H11}}}{\text{PJMWHLMP}_{\text{June } 3, 2009 \text{ H11}}}$$

Exhibit 24: Three Hourly Basis Differential Ratios Values for the same hour in Each of Three Historical Years

Once the hourly basis ratios are calculated for every hour in the historic period take the sum of the on-peak hourly basis differentials, and divide by the number of peak hours. Similarly sum the off-peak hourly basis ratios, for the month then divide by the number of off-peak hours. When calculating the intra-month peak basis differential ratio, all days in the month will be used for the average. The intra-month basis differentials adjust PJM Western Hub daily peak and off-peak DA prices to expected peak and off-peak daily forward prices delivered to the generator's bus.

$$\begin{aligned}
 & \text{MonthlyPeakBasisDifferentialRatio}_{y,m}^{\text{peak}} \\
 &= \frac{\sum_{\text{peak hours}} (\text{HourlyBasisDifferentialRatios}_{y,m}^{\text{peak}})}{\text{Number of Peak Hours in month } m} \\
 & \text{MonthlyPeakBasisDifferentialRatio}_{y,m}^{\text{peak}} \\
 &= \frac{\sum_{\text{off-peak hours}} (\text{HourlyBasisDifferentialRatios}_{y,m}^{\text{off-peak}})}{\text{Number of Off-Peak Hours in month } m} \\
 & \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2007}}^{\text{peak}} \\
 &= \frac{\sum_{\text{peak hours}} (\text{HourlyBasisDifferentialRatios}_{\text{June 2007}}^{\text{peak}})}{\text{Number of peak hours in June 2007}} \\
 & \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2008}}^{\text{peak}} \\
 &= \frac{\sum_{\text{peak hours}} (\text{HourlyBasisDifferentialRatios}_{\text{June 2008}}^{\text{peak}})}{\text{Number of peak hours in June 2008}} \\
 & \text{MonthlyPeakBasisDifferentialRatio}_{\text{June 2009}}^{\text{peak}} \\
 &= \frac{\sum_{\text{peak hours}} (\text{HourlyBasisDifferentialRatios}_{\text{June 2009}}^{\text{peak}})}{\text{Number of peak hours in June 2009}}
 \end{aligned}$$

Exhibit 25: Monthly Peak Basis Differentials for the Three Historical Periods

Multiply peak and off-peak basis differential ratios by the respective peak and off-peak PJM Western hub forwards to derive forecasted peak and off-peak bus prices for each historical year. When calculating the intra-monthly peak basis differential ratio all days in the month will be used for the average.

$$\begin{aligned}
 & \text{Forecasted Montly Bus Price}_{fy,m}^{\text{peak}} \\
 &= [(\text{PJMWesternHub}_{fy,m}^{\text{peak}}) * (\text{MonthlyPeakBasisRatio}_{y,m}^{\text{peak}})] \\
 & \text{Forecasted Montly Bus Price}_{\text{June 2010, base 2007}}^{\text{OFFpeak}} \\
 &= [(\text{PJMWH}_{\text{for delivery June 2010}}^{\text{OFFpeak}}) * (\text{MonthlyOffPeakBasisDifferentialRatio}_{\text{June 2007}}^{\text{OFFpeak}})]
 \end{aligned}$$

$$\begin{aligned}
 & \text{Forecasted Montly Bus Price}_{\text{June 2010, base 2008}}^{\text{OFFpeak}} \\
 &= \left[\left(\text{PJMWH}_{\text{for delivery June 2010}}^{\text{OFFpeak}} \right) * \left(\text{MonthlyOffPeakBasisDifferentialRatio}_{\text{June 2008}}^{\text{OFFpeak}} \right) \right] \\
 & \text{Forecasted Montly Bus Price}_{\text{June 2010, base 2009}}^{\text{OFFpeak}} \\
 &= \left[\left(\text{PJMWH}_{\text{for delivery June 2010}}^{\text{OFFpeak}} \right) * \left(\text{MonthlyOffPeakBasisDifferentialRatio}_{\text{June 2009}}^{\text{OFFpeak}} \right) \right]
 \end{aligned}$$

Exhibit 26: Forecasted Monthly Bus Prices for Three Historical Periods

Outputs for STEP 1: Three peak and off-peak monthly BUS LMP forecasts for the remaining days in a month

12.6.2 Step 2: Derive hourly volatility scalars to incorporate hourly volatility into the LMP forecast

Inputs required for STEP 2: Three years historical hourly real-time LMPs at the generation bus

Daily forward prices are the average peak and off-peak prices for the next day and do not include hourly LMP volatility. Step 2 derives an hourly volatility scalar. This scalar will later be multiplied against the forecasted prices in Step 1 to develop an hourly bus LMP forecast that incorporates historic hourly peak and off-peak LMP volatility.

First, for each historic month compute the average peak and off-peak price at the unit's bus for the intra-month. When calculating the monthly average bus LMP all days in the month will be used for the average.

$$\begin{aligned}
 & \text{MonthlyAverageBusLMP}_{y,m}^{\text{peak}} \\
 &= \frac{\sum_{\text{peak hours}} (\text{HourlyBusLMP}_{y,m,d,h}^{\text{peak}})}{\text{Number of Peak hours in month } m} \\
 & \text{MonthlyAverageBusLMP}_{y,m}^{\text{off-peak}} \\
 &= \frac{\sum_{\text{off-peak hours}} (\text{HourlyBusLMP}_{y,m,d,h}^{\text{off-peak}})}{\text{Number of Off-Peak hours in month } m}
 \end{aligned}$$

Next, for every hour, take the hourly bus LMP divided by the relevant monthly average peak or off-peak bus LMP computed above. If the hour is an on-peak hour, divide by the average peak LMP for the month.

$$\text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{peak}} = \frac{\text{BUSLMP}_{y,m,d,h}^{\text{peak}}}{\text{MonthlyAverageBusLMP}_{y,m}^{\text{peak}}}$$

If the hour is off-peak, divide that hour by the monthly off-peak average price for the corresponding month.

$$\text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{off-peak}} = \frac{\text{BUSLMP}_{y,m,d,h}^{\text{off-peak}}}{\text{MonthlyAverageBusLMP}_{y,m}^{\text{off-peak}}}$$

Example 10.1: Volatility scalar for the each of the three historical years:

$$\text{HourlyVolatilityScalar}_{\text{June 3, 2007 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2007 H23}}}{\text{Average Offpeak June 2007 BUSLMP}}$$

$$\text{HourlyVolatilityScalar}_{\text{June 3, 2008 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2008 H23}}}{\text{Average Offpeak June 2008 BUSLMP}}$$

$$\text{HourlyVolatilityScalar}_{\text{June 3, 2009 H23}} = \frac{\text{BUSLMP}_{\text{June 3, 2009 H23}}}{\text{Average Offpeak June 2009 BUSLMP}}$$

Outputs from STEP 2: Three ratio values per hour for each of the historical years used for volatility.

12.6.3 Step 3: Create three sets of hourly forecasted bus values

Inputs required for STEP 3: Output from Step 1: On-peak/off-peak monthly bus LMP Forecast Output from Step 2: Hourly volatility scalars

Step 3 creates three hourly forecasts from the volatility scalars developed in step 2 and the monthly bus LMP forecasts developed in Step 1. Multiply the hourly volatility scalars developed in step 2 by the corresponding peak or off-peak from the historical year forecasted monthly bus price calculated in Step 1.

The expected or forecasted LMP for hour h, day d, month m, based on year y that is a peak hour is:

$$\begin{aligned} & \text{ForecastedBUSLMP}_{y,m,d,h}^{\text{peak}} \\ & = \text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{peak}} * \text{ForecastedMonthlyBusPrice}_{f,y,m}^{\text{peak}} \end{aligned}$$

The expected or forecasted LMP for hour h, day d, month m, based on year y that is an off-peak hour is:

$$\begin{aligned} & \text{ForecastedBUSLMP}_{y,m,d,h}^{\text{off-peak}} \\ & = \text{HourlyVolatilityScalar}_{y,m,d,h}^{\text{off-peak}} * \text{ForecastedMonthlyBusPrice}_{f,y,m}^{\text{off-peak}} \end{aligned}$$

Example 11.1: Forecasted bus LMPs for one hour for each of the three historical base years:

To create the set of three forecasted prices for each hour of June 3, 2010:

$$\begin{aligned}
 & \text{ForecastedBUSLMP}_{\text{June 3, 2010 H00,base 2007}} \\
 &= \text{HourlyVolatilityScalar}_{\text{June 3,2007 H00}} * \text{ForecastedMontlyBusPrice}_{\text{June 2010}}^{\text{offpeak}} \\
 & \text{ForecastedBUSLMP}_{\text{June 3, 2010 H00,base 2008}} \\
 &= \text{HourlyVolatilityScalar}_{\text{June 3,2008 H00}} * \text{ForecastedMontlyBusPrice}_{\text{June 2010}}^{\text{offpeak}} \\
 & \text{ForecastedBUSLMP}_{\text{June 3, 2010 H00,base 2009}} \\
 &= \text{HourlyVolatilityScalar}_{\text{June 3,2009 H00}} * \text{ForecastedMontlyBusPrice}_{\text{June 2010}}^{\text{offpeak}}
 \end{aligned}$$

Outputs from STEP 3: Three hourly bus LMP forecasts for each hour remaining in the compliance period

12.6.4 Step 4: Fuel Price

**Inputs required for STEP 4: Fuel Weights if dual fuel
 Contract Fuel Prices if Applicable**

In the short term method, no volatility is applied to the fuel prices. Take the Day Ahead Price for the appropriate fuel; add the delivery adder and this is the appropriate fuel price to use.

For units that have dual fuels; the daily delivered fuel prices need to be multiplied by their respective weights and then added together. If there is no fuel cost record for a given date, use the previous available value.

For units with some or all of their fuel procured by contract, the contract and DA fuel prices are multiplied by their respective weights (derived from expected use of each fuel) and added together and then multiplied by the daily fuel volatility scalar. The current daily delivery charge adjustment will be applied through the compliance period.

Unit with a single fuel:

$$\begin{aligned}
 & \text{Daily Delivered Fuel}_{y,m,d} \\
 &= \text{WeightSpot}_m * (\text{Day Ahead Fuel Price} + \text{Delivery Adjustment}) \\
 & \quad + (\text{WeightSpot}_m + (\text{WieghtContract}_m * \text{ContractPrice}_m)) \\
 & \text{Where Weight Contract}_m + \text{Weight Spot}_m = 1
 \end{aligned}$$

Unit with duel fuel:

The following equation permits use of dual fuels for units that may burn multiple fuels or source fuels from different areas at different prices. For units with restrictions on consumption of specific fuels, this method allows accounting for both fuels in the same calculation.

$$\begin{aligned}
 & \text{DailyDeliveredFuel}_{fy,m,d} \\
 & = [\text{WeightFuelTypeA}_m \\
 & \quad * (\text{WeightContractFuelTypeA}_m \\
 & \quad \quad * \text{ContractPriceFuelTypeA}_m \\
 & \quad \quad + \text{WeightSpotFuelTypeA}_m \\
 & \quad \quad * (\text{DeliveryAdjustmentFuelTypeA} + \text{FuelForwardFuelTypeA}_{fy,m})) \\
 & + \text{WeightFuelTypeB}_m * \text{ContractPriceFuelTypeB}_m + \text{WeightSpotFuelTypeB}_m \\
 & \quad * (\text{DeliveryAdjustmentFuelTypeB} + \text{FuelForwardFuelTypeB}_{fy,m})) \\
 & \quad \text{Where Weight Fuel Type A}_m + \text{Weight Fuel Type B}_m = 1 \\
 & \quad \text{Where Weight Contract Type A}_m + \text{Weight Spot Type A}_m = 1 \\
 & \quad \text{Where Weight Contract Type B}_m + \text{Weight Spot Type B}_m = 1
 \end{aligned}$$

Output from STEP 4: Daily generator-bus delivered fuel forecast

12.6.5 Step 5: Create generating unit's cost for each of the three forecasts

Inputs required for STEP 5: Expected future full heat rate intra-month Fuel Prices output from Step 4 Unit SO₂, CO₂, and NO_x Emission Rates (lbs/M (Note that the CO₂ adder is in effect only for incurring carbon emission charges) Futures prices for SO₂, CO₂ and NO_x from Evolution Markets (\$/ton) modified to \$/lb Maintenance Adder, VOM and FMU as defined in Manual 15

In Step 5, take the unit characteristics, future emission allowance prices, the three daily fuel forecasts and create a daily unit cost for the three forecasts using the appropriate heat rate for the forecast day. Unit costs do not include Start-up Costs, Start-up Costs will be added later in the calculation of Unit Dispatch Cost. For each day in the three fuel forecasts, a unit dispatch cost is calculated as follows:

$$\begin{aligned}
 & \text{UnitCost}_{fy,m,d}^{\text{base year}} \\
 & = \left\{ \left[\text{Unit Heat Rate} \left(\frac{\text{MMBtu}}{\text{MWh}} \right) * \text{Daily Delievered Fuel Forecast} \left(\frac{\$}{\text{MMBtu}} \right)_{\text{Future } y,m,d}^{\text{base year}} \right] \right\}
 \end{aligned}$$

$$\begin{aligned}
 &+ \left[\text{Unit Heat Rate} \left(\frac{\text{MMBtu}}{\text{MWh}} \right) * \text{Unit NO}_x \text{Emission Rate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of NO}_x \left(\frac{\$}{\text{lb}} \right) \right] \\
 &+ \left[\text{Unit Heat Rate} \left(\frac{\text{MMBtu}}{\text{MWh}} \right) * \text{Unit SO}_2 \text{Emission Rate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of SO}_2 \left(\frac{\$}{\text{lb}} \right) \right] \\
 &+ \left[\text{Unit Heat Rate} \left(\frac{\text{MMBtu}}{\text{MWh}} \right) * \text{Unit CO}_2 \text{Emission Rate} \left(\frac{\text{lbs}}{\text{MMBtu}} \right) * \text{Cost of CO}_2 \left(\frac{\$}{\text{lb}} \right) \right] \\
 &\quad + \text{VOM} \} + \text{either } a_{\text{FMU adder}}^{10\% \text{ margin or}}
 \end{aligned}$$

Unit heat rate=10.345 MMBtu/MWh

Unit NO_x emission rate =0.328 lbs/MMBtu

Unit SO₂ emission rate=1.2 lbs/MMBtu

Unit CO₂ emission rate=117 lbs/MMBtu

DailyDeliveredFuelForecast=\$3.01/MMBtu

Combined NO_x Allowance cost=\$1375/ton

SO₂ Allowance cost=\$200/ton

CO₂ emission cost = \$8/ton

VOM & Maintenance Adder=\$2.22/MWh

FMU= \$0.00/MWh

$$\begin{aligned}
 \text{Unit Cost} = & \{ [10.345(\text{MMBtu} / \text{MWh}) * \$3.01(\$/ \text{MMBtu})] + [10.345(\text{MMBtu} / \text{MWh}) \\
 & * 0.328(\text{lbs} / \text{MMBtu}) * 0.6875(\$/ \text{lb})] + [10.35(\text{MMBtu} / \text{MWh}) * 1.2(\text{lbs} / \text{MMBtu}) \\
 & * 0.1(\$/ \text{lb})] + [10.345(\text{MMBtu} / \text{MWh}) * 117(\text{lbs} / \text{MMBtu}) * 0.004(\$/ \text{lb})] + \$2.22 \}
 \end{aligned}$$

$$\begin{aligned}
 \text{Unit Cost} = & \{ [(\$31.14 / \text{MWh})] + [(\$2.33 / \text{MWh})] + \\
 & [(\$1.24)] + [(\$4.84 / \text{MWh})] + \$2.22 \} = \$41.77 / \text{MWh}
 \end{aligned}$$

Exhibit 27: Daily Unit Cost

Outputs from STEP 5: Three forecasts based on historic year factors for daily generator unit cost

12.6.6 Step 6: Calculate the margin for every hour in the three hourly forecasts

Inputs required for STEP 6: Daily Generator Unit Cost
 Hourly Generator bus LMP forecast from Step 3 Unit-specific minimum run-time parameter restriction Unit-specific Start-up Costs (cold Start-up costs for CC and

CT units and hot Start-up Costs for steam units) Unit economic maximum

Step 6 calculates the hourly margin the generator would receive by comparing the cost offer developed in step 5 against the hourly forecasted bus LMPs developed in step 3.

For units with minimum run time restrictions, this step calculates total margins in blocks of adjacent hours, based on the sum of the margins of each block and the minimum run time parameter restriction of the unit. Blocks may include additional incremental hours, if these hours are found to be more valuable than an additional block, up to double a unit's minimum run time. Adjacent hour blocks with equal or greater number of hours than double a unit's minimum run time will be split into multiple blocks (however adjacent blocks do not use an additional Start-up Cost). For units with Start-up Costs, the value of the unit's Start-up Cost divided by economic maximum will be subtracted from the total margin of each block that contains a new start, but not from each subsequent incremental hour added to the block, in order to correctly value hours that do not incur Start-up Costs. Calculate the total margins for all blocks of hours in the three forecasts:

$$TotalMarginBlock_{t=block+MRT-1}^{base\ year\ block} = \sum_{t=block} (ForecastedBusLMP_{y(t),m(t),d(t),h(t)}^{base\ year} - UnitDispatchCost_{future\ y, m, d}^{base\ year})$$

**MRT= minimum run time

Where block ranges from 1 to [totalNumberofHours – MinRunTime + 1] and y(t), m(t), d(t), h(t) are the year, month, day and hour corresponding to the overall hour of the time period spanning from the date calculated to the end of the intra-month period.

The totalNumberofHours variable represents the number of hours left intra-month to be forecasted, and is based on the date.

This example uses block # 3679:

$$\begin{aligned} TotalMarginBlock_{block\ 3679}^{2007} &= \sum_{t=block+MRT-1} (ForecastedBUSLMP_{y(t),m(t),d(t),h(t)}^{block} - UnitDispatchCost_{future\ y, m, d}^{base\ year}) \\ &= \sum_{t=3678}^{t=3679+1-1} (ForecastedBUSLMP_{y(t),m(t),d(t),h(t)}^{2007} - UnitDispatchCost_{future\ y, m, d}^{2007}) \\ &= ForecastedBusLMP_{June\ 3, 2010\ H02}^{2007} - UnitDispatchCost_{June\ 3, 2010}^{2007} \\ &= \$53.23 - \$41.77 = -\$11.46 \end{aligned}$$

Similarly

$$\begin{aligned}
 & \text{TotalMarginBlock}_{\text{block } 3679}^{2008} \\
 &= \text{ForecastedBusLMP}_{\text{June 3, 2010 H02}}^{2008} - \text{UnitDispatchCost}_{\text{June 3, 2010}}^{2008} \\
 &= \$55.44 - \$57.88 = -\$2.44
 \end{aligned}$$

And

$$\begin{aligned}
 & \text{TotalMarginBlock}_{\text{block } 3679}^{2009} \\
 &= \text{ForecastedBusLMP}_{\text{June 3, 2010 H02}}^{2009} - \text{UnitDispatchCost}_{\text{June 3, 2010}}^{2009} \\
 &= \$49.78 - \$49.72 = -\$0.06
 \end{aligned}$$

Exhibit 28: Calculating Total Margins with a minimum run time of one hour (i.e. no minimum run time restriction), using historical data from the past three calendar years

At this point, the blocks of hours would be ranked according to the value of their total margins.

Outputs from STEP 6: Three sets of ranked blocks of total margin forecasts including each hour in the compliance period, adjusted to include Start-up Costs for each block that contains a new start, with all future outage hours removed

12.6.7 Step 7: Determine the opportunity cost adder

Inputs required for STEP 7: Three sets of ranked blocks of total margin forecasts

For each of the three years, the opportunity cost for that year will be the average total margin of the lowest value block added before the run hour limit was reached. The three opportunity costs will then be averaged to get the opportunity cost adder available to the generator. If the opportunity cost adder is less than 0, the opportunity cost adder will be set to 0.

The average value of the block which includes the 700th hour_{base2007} = \$18.33 MWh

The average value of the block which includes the 700th hour_{base2008} = \$-2.50 MWh

The average value of the block which includes the 700th hour_{base2009} = \$1.59 MWh

700th hour opportunity cost adder = \$18.33 + (-\$2.50) + \$1.59 / 3 = \$5.81 / MWh

Exhibit 29: A Unit with 700 run hours left

*Output from STEP 7: Maximum Opportunity Cost
Component that can be added to an environmentally run
limited generator's cost offer.*

12.7 IMM Opportunity Cost Calculator

The IMM Opportunity Cost Calculator is a constrained optimization software application independently developed and owned by Monitoring Analytics, LLC. Any changes to the IMM Calculator must be approved by Monitoring Analytics, LLC. The IMM will notify PJM of any significant changes to the IMM Opportunity Cost Calculator and any such changes will be reflected in updates to Manual 15 Section 12.7. PJM will review any such changes to verify that the IMM Opportunity Cost Calculator continues to meet the requirements of Schedule 2 of the Operating Agreement.

On an annual basis, PJM will review the inputs and results of the IMM Opportunity Cost Calculator in consultation with the IMM to verify that the IMM Opportunity Cost Calculator continues to meet the documented requirements.

12.7.1 Calculation Method

The Opportunity Cost Calculator selects the hours of operation that will maximize the generator's energy market revenue net of the generator's short run marginal cost of producing energy, subject to the unit specific environmental or operational limits. The duration and structure (i.e. rolling compliance periods or a single compliance period) of the optimization period will be as specified in an environmental permit for environmental limitations, or as specified by the original equipment manufacturer or insurance carrier for physical equipment limitations. In the case of a fuel supply limitation, the duration of the optimization period must be approved by PJM and the MMU.

Inputs into the Opportunity Cost Calculator will include unit specific forward LMPs based on futures prices, unit specific forward fuel prices based on futures or contract prices, and unit specific operating parameters.

The opportunity cost is the shadow price corresponding to the binding environmental or operational limit. The shadow price is defined as the marginal decrease in the net revenue due to a one hour equivalent decrease in the binding environmental or operational limit. Opportunity cost therefore is the marginal value of the foregone opportunity to earn higher profits for an environmentally or operationally constrained unit¹.

Energy Market Opportunity Costs and Non-Regulatory Opportunity Costs are a distinct component of the cost-based offer. As is the case with any computation of the cost-based offer in Manual 15, Market Sellers may elect to enter their cost-based offer at a value less than the computed cost-based offer. However, they may not exceed the computed value.

¹ A separate opportunity cost adder, applicable to a specific portion of the generator's offer curve, may be appropriate for an environmental or operational limitation that applies to the duct fire capability of the generator (e.g. duct fire hours limit). If it is determined that a duct fire limit is binding, the corresponding opportunity cost is the shadow price corresponding to the duct fire limit.

12.7.2 Forward LMP

Unit specific hourly forward LMPs are based on off peak and on peak future contracts for PJM Western Hub or any neighboring frequently traded PJM hub with expiration dates during the optimization period. The futures contract price will be multiplied by a basis differential and an hourly volatility scalar. The basis differential accounts for the price difference between the location of the forward contract delivery point (PJM Western Hub) and the relevant generator bus. The hourly volatility scalar incorporates hourly volatility into the forward LMP.

Three different historical time periods will be identified and mapped on an hourly basis to the optimization period. Historical on peak hours will be mapped to on peak hours in the optimization period, and historical off peak hours will be mapped to off peak hours in the optimization with adjustments made to ensure historical holiday and weekend days are mapped to holiday and weekend days during the optimization period. For example, if the calculation date is January 25, 2019 and the optimization period is one year into the future, then three different historical time periods, each consisting of 8,760 hours from the three year period preceding January 25, 2019, will be identified. Each of the three historical time periods will be mapped to the 8,760 hours in the optimization period such that on peak hours are mapped to on peak hours, off peak hours are mapped to off peak hours, holidays are mapped to holidays, and weekend days are mapped to weekend days.

Three on peak and three off peak basis differentials will be computed for each futures contract used in the calculation of the forward LMPs using the three historical time period mappings. The on peak basis differential will be calculated as the average of the ratio of the hourly bus LMP to the hourly Western Hub LMP, with the average being taken over all on peak hours during the identified historical time period where the month corresponds to the futures contract month of expiry. The off peak basis differential will be calculated as the average of the ratio of the hourly bus LMP to the hourly Western Hub LMP, with the average being taken over all off peak hours during the identified historical time period where the month corresponds to the futures contract month of expiry.

Three hourly volatility scalars will be computed for each hour during the optimization period based on the three different historical time period mappings. For an on peak hour in the optimization period, the hourly volatility scalar will be calculated as the ratio of the historical bus LMP to the average historical bus LMP, with the average being taken over all on peak hours during the identified historical time period where the month corresponds to the month of the on peak hour in the optimization period. For an off peak hour in the optimization period, the hourly volatility scalar will be calculated as the ratio of the historical bus LMP to the average historical bus LMP, with the average being taken over all off peak hours during the identified historical time period where the month corresponds to the month of the off peak hour in the optimization period.

12.7.3 Forward Delivered Fuel Price

Unit specific daily forward delivered fuel prices are based on traded forward fuel prices from a published source or prior contractually agreed prices. A fuel delivery charge is added to the monthly forward fuel prices to obtain delivered fuel prices, and the delivered fuel prices are multiplied by daily volatility scalars to obtain a daily forward delivered fuel price for the generator. For generators procuring fuel at a contractual rate, a volatility scalar is not applied and a constant contracted price is used. Three volatility scalars are computed for each day in the optimization period based on the three different historical time period mappings. The daily

volatility scalar is computed as the ratio of the historical daily delivered fuel price to the average monthly historical delivered fuel price.

12.7.4 Operating Cost

The hourly operating cost (\$ per MWh) is the short run marginal cost of generating energy. Inputs into the calculation of the hourly operating cost consist of the forward delivered fuel price, the generator's heat rate data, emission rate data, and VOM cost available in the Member Information Reporting Application (MIRA), and emission futures prices. The calculation of hourly operating cost is consistent with the calculation of cost based offers specified in PJM Manual 15.

The hourly operating cost or operating parameters may be adjusted in cases where the unit's historical offer behavior deviates from the short run marginal cost or the commitment and dispatch of the generator has historically differed from expected economic outcomes due to actions taken by the Transmission Provider or other factors outside the control of the Market Participant. The application, and the magnitude and direction, of any adjustment is dependent upon an expectation that the offer behavior or conditions that cause the noneconomic commitment and dispatch of the unit will persist into the optimization period and that the unit will be subject to mitigation.

12.7.5 Emissions and Operating History

Up to date emissions totals, hours of operations, or number of starts are critical inputs into the Opportunity Cost Calculator. Market Participants are required to provide these values on a routine basis and as requested by the MMU. If Market Participants fail to provide emissions data at the required temporal granularity, actual generation history and the generator's emissions rates and heat rate will be used to calculate daily emissions. Opportunity cost adders will not be calculated for generators that do not have up to date emissions totals, hours of operations, or number of starts, and Market Participants will not be allowed to include an opportunity cost adder in the generator's cost based offer.

12.7.6 Opportunity Cost Adder

For each of the three sets of forward LMPs and forward delivered fuel prices, the Opportunity Cost Calculator selects the hours of operation that maximize the generator's energy market revenue net of the generator's short run marginal cost of producing energy, subject to the unit specific environmental or operational limits. The duration and structure (i.e. rolling compliance periods or a single compliance period) of the optimization period will be as specified in an environmental permit for environmental limitations, as specified by the original equipment manufacturer or insurance carrier for physical equipment limitations, or as agreed upon by the Market Participant, PJM and the MMU in cases of fuel supply limitations².

For resources with a single compliance period (e.g. calendar year), the opportunity cost is the shadow price corresponding to the binding environmental or operational limit. For resources with rolling compliance periods, the opportunity cost is the shadow price corresponding to the

² The required opportunity cost is a solution of a constrained optimization problem and the IMM Opportunity Cost Calculator uses an integer programming solver that finds the maximum energy market revenue net of the generator's short run marginal cost of producing energy while simultaneously satisfying all generator parameter limits (e.g. minimum run time, economic minimum economic maximum) and environmental or operational limits.

earliest binding environmental or operational limit. The shadow price is defined as the marginal decrease in the net revenue due to a one hour equivalent decrease in the binding environmental or operation limit.

The opportunity cost adder is calculated as the average of the three opportunity cost values corresponding to the three sets of forward LMPs and forward delivered fuel prices.

12.7.7 Market Participant Requirements

Market Participants must make available to the MMU the following information:

- Permits describing environmental limitations imposed on the generator;
- OEM documentation or insurance carrier documentation for physical equipment limitations;
- Operating parameters necessary for the calculation (Economic Minimum, Economic Maximum, heat rate curve, minimum downtime, maximum weekly starts, maximum daily starts, emission rates, start-up emission rates, fuel consumption rates during start-up);
- Fuel price information;
- Emission levels for the previous 12 month period in the case of environmental limitations;
- Hours of operation and number of starts for generators subject to operational limitations.

Information that is currently included in the Cost Offer Assumptions (COA) or the Fuel Policy as part of the Member Information Reporting Application (MIRA) does not need to be resubmitted.

12.7.8 Dual Fuel Opportunity Cost Adder

Dual fuel generators with an environmental or operational limitation that applies regardless of the fuel type may use the dual fuel opportunity cost adder in the cost schedule associated with the secondary fuel. The dual fuel opportunity cost adder is determined under the assumption that the generator operated for the minimum run time on the first day of the optimization period using the secondary fuel. For the remaining days in the optimization period, the generator is dispatched according to a daily determination of the cheaper fuel based on forward prices modified by the historical daily volatility. The opportunity cost adder applicable to the cost schedule associated with the primary fuel is determined according to Sections 12.7.1-12.7.7.

Attachment A: Applicable FERC System of Accounts

The information included in this Attachment A provides the descriptions and definitions of several account numbers and Operating Expenses Instructions as they appear in the **FERC System of Accounts** and named in this document.

The **FERC System of Accounts** was created when a predominant amount of the nation's electrical generating resources were "**utility owned**". Although many of those resources are now owned by non-vertically integrated entities, such as, Independent Power Producers (IPPs) and Generating Companies (GENCOs), the descriptions of the accounts are the important concepts.

Accounting Principal Regarding FERC System of Accounts

Whenever there is reference in this manual to a FERC Account, it is implicitly understood that the FERC System of Accounts may be replaced by any other accounting method mapped back to the current FERC System of Accounts (see Attachment B) if approved for use by the MMU. The accounts named in this document provide the information to allow the development of cost based bids for submission to PJM.

A.1 Balance Sheet Accounts

A.1.1 FERC FORM 1 ACCOUNT 151: Fuel Stock (Major only).

This account shall include the book cost of fuel on hand.

Items

- Invoice price of fuel less any cash or other discounts.
- Freight, switching, demurrage and other transportation charges, not including, however, any charges for unloading from the shipping medium.
- Excise taxes, purchasing agents' commissions, insurance and other expenses directly assignable to cost of fuel.
- Operating, maintenance and depreciation expenses and ad valorem taxes on utility-owned transportation equipment used to transport fuel from the point of acquisition to the unloading point.
- Lease or rental costs of transportation equipment used to transport fuel from the point of acquisition to the unloading point.

A.2 Expense Accounts

A.2.1 FERC FORM 1 ACCOUNT 501: Fuel

- This account shall include the cost of fuel used in the production of steam for the generation of electricity, including expenses in unloading fuel from the shipping media and handling thereof up to the point where the fuel enters the first boiler plant bunker, hopper, bucket, tank or holder of the boiler-house structure. Records shall be maintained to show the quantity, MMBtu content and cost of each type of fuel used.

- The cost of fuel shall be charged initially to Account 151, Fuel Stock (for Non-major utilities, appropriate fuel accounts carried under Account 154, Plant Materials and Operating Supplies), and cleared to this account on the basis of the fuel used. Fuel handling expenses may be charged to this account as incurred or charged initially to Account 152, Fuel Stock Expenses Undistributed (for Non-major utilities, an appropriate sub account of Account 154, Plant Materials and Operating Supplies). In the latter event, they shall be cleared to this account based on the fuel used. Respective amounts of fuel stock and fuel stock expenses shall be readily available.

Items**Labor:**

- Supervising purchasing and handling of fuel.
- All routine fuel analysis.
- Unloading from shipping facility and putting in storage.
- Moving of fuel in storage and transferring fuel from one station to another.
- Handling from storage or shipping facility to first bunker, hopper, bucket, tank or holder of boiler-house structure.
- Operation of mechanical equipment, such as locomotives, trucks, cars, boats, barges, cranes, etc.

Materials and expenses:

- Operating, maintenance and depreciation expenses and ad valorem taxes on utility-owned transportation equipment used to transport fuel from the point of acquisition to the unloading point (Major only).
- Lease or rental costs of transportation equipment used to transport fuel from the point of acquisition to the unloading point (Major only).
- Cost of fuel including freight, switching, demurrage and other transportation charges.
- Excise taxes, insurance, purchasing commissions and similar items.
- Stores expense to extent applicable to fuel.
- Transportation and other expenses in moving fuel in storage.
- Tools, lubricants and other supplies.
- Operating supplies for mechanical equipment.
- Residual disposal expenses less any proceeds from sale of residuals.

Note:

Abnormal fuel handling expenses occasioned by emergency conditions shall be charge to expense as incurred.

A.2.2 FERC FORM 1 ACCOUNT 509: Allowances

This account shall include the cost of allowances expensed concurrent with the monthly emission of sulfur dioxide.

A.2.3 FERC FORM 1 ACCOUNT 512: Maintenance of Boiler Plant (Major only)

- This account shall include the cost of labor, materials used and expenses incurred in the maintenance of steam plant, the book cost of which is includible in Account 312, Boiler Plant Equipment. (See operating expense instruction 2; which can be found in this manual, Attachment A.3.1)
- For the purposes of making charges hereto and to Account 513, Maintenance of Electric Plant, the point at which steam plant is distinguished from electric plant is defined as follows:
 - o Inlet flange of throttle valve on prime mover.
 - o Flange of all steam extraction lines on prime mover.
 - o Hotwell pump outlet on condensate lines.
 - o Inlet flange of all turbine-room auxiliaries.
 - o Connection to line side of motor starter for all boiler-plant equipment.

A.2.4 FERC FORM 1 ACCOUNT 513: Maintenance of Electric Plant (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of electric plant, the book cost of which is includible in Account 313, Engines and Engine-Driven Generators, Account 314, Turbogenerator Units, and Account 315, Accessory Electric Equipment. (See operating expense instruction 2, which can be found in this manual, Attachment A.3.1 and paragraph B of Account 512, which can be found above in A.2.3)

A.2.5 FERC FORM 1 ACCOUNT 518: Nuclear Fuel Expense (Major only)

- This account shall debit and Account 120.5, Accumulated Provision for Amortization of Nuclear Fuel Assemblies, credited for the amortization of the net cost of nuclear fuel assemblies used in the production of energy. The net cost of nuclear fuel assemblies subject to amortization shall be the cost of the nuclear fuel assemblies plus or less the expected net salvage of uranium, plutonium, and other byproducts and unburned fuel. The utility shall adopt the necessary procedures to assure that charges to this account are distributed according to the thermal energy produced in such periods.
- This account shall also include the costs involved when fuel is leased.
- This account shall also include the cost of other fuels, used for ancillary steam facilities, including superheat.
- This account shall be debited or credited as appropriate for significant changes in the amounts estimated as the net salvage value of uranium, plutonium, and other byproducts contained in Account 157, Nuclear Materials Held for Sale and the amount realized upon the final disposition of the materials. Significant declines in the estimated realizable value of items carried in Account 157 may be recognized at the time of market price declines by charging this account and crediting Account 157. When the declining

change occurs while the fuel is recorded in Account 120.3, Nuclear Fuel Assemblies in Reactor, the effect shall be amortized over the remaining life of the fuel.

A.2.6 FERC FORM 1 ACCOUNT 530: Maintenance of Reactor Plant Equipment (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of reactor plant, the book cost of which is includible in Account 322, Reactor Plant Equipment.

A.2.7 FERC FORM 1 ACCOUNT 531: Maintenance of Electric Plant (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of electric plant, the book cost of which is includible in Account 323, Turbo-generator Units, and account 324, Accessory Electric Equipment.

A.2.8 FERC FORM 1 ACCOUNT 543: Maintenance of Reservoirs, Dams, and Waterways (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of plant, includible in Account 332, Reservoirs, Dams, and Waterways. (See operating expense instruction 2, which can be found in this manual, Attachment A.3.1.) However, the cost of labor materials used and expenses incurred in the maintenance of fish and wildlife, and recreation facilities, the book cost of which is includible in Account 332, Reservoirs, Dams, and Waterways, shall be charged to Account 545, Maintenance of Miscellaneous Hydraulic Plant.

A.2.9 FERC FORM 1 ACCOUNT 544: Maintenance of Electric Plant (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of plant includible in Account 333, Water Wheels, Turbines and Generators, and Account 334, Accessory Electric Equipment. (See operating expense instruction 2, which can be found in this manual, Attachment A.3.1.)

A.2.10 FERC FORM 1 ACCOUNT 553: Maintenance of Generating and Electrical Equipment (Major only)

This account shall include the cost of labor, materials used and expenses incurred in the maintenance of plant, the book cost of which is includible in Account 343, Prime Movers, Account 344, Generators, and Account 345, Accessory Electric Equipment.

A.3 Operating Expense Instructions 2 and 3

A.3.1 OPERATING EXPENSE INSTRUCTION 2: Maintenance

- The cost of maintenance chargeable to the various operating expense and clearing accounts includes labor, materials, overheads and other expenses incurred in maintenance work. A list of work operations applicable generally to utility plant is included hereunder. Other work operations applicable to specific classes of plant are listed in functional maintenance expense accounts.
- Materials recovered in connection with the maintenance of property shall be credited to the same account to which the maintenance cost was charged.

- If the book cost of any property is carried in Account 102, Electric Plant Purchased or Sold, the cost of maintaining such property shall be charged to the accounts for maintenance of property of the same class and use, the book cost of which is carried in other electric plant in service accounts. Maintenance of property leased from others shall be treated as provided in operating expense instruction 3.

Items

- Direct field supervision of maintenance
- Inspecting, testing, and reporting on condition of plant specifically to determine the need for repairs, replacements, rearrangements and changes and inspecting and testing the adequacy of repairs that have been made
- Work performed specifically for the purpose of preventing failure, restoring serviceability or maintaining life of plant
- Rearranging and changing the location of plant not retired
- Repairing for reuse materials recovered from plant
- Testing for locating and clearing trouble
- Net cost of installing, maintaining, and removing temporary facilities to prevent interruptions in service
- Replacing or adding minor items of plant that do not constitute a retirement unit (See electric plant instruction 10)

Note:

ELECTRIC PLANT INSTRUCTION 10 Rents includes amounts paid for the use of construction quarters and office space occupied by construction forces and amounts properly includible in construction costs for such facilities jointly used.

A.3.2 OPERATING EXPENSE INSTRUCTION 3: Rents

- The rent expense accounts provided under the several functional groups of expense accounts shall include all rents, including taxes paid by the lessee on leased property, for property used in utility operations, except (1) minor amounts paid for occasional or infrequent use of any property or equipment and all amounts paid for use of equipment that, if owned, would be includible in plant Accounts 391 and 398, inclusive, which shall be treated as an expense item and included in the appropriate functional account and (2) rents which are chargeable to clearing accounts, and distributed there from/to the appropriate account. If rents cover property used for more than one function, such as production and transmission, or by more than one department, the rents shall be apportioned to the appropriate rent expense or clearing accounts of each department on an actual, or if necessary, an estimated basis.
- When a portion of property or equipment rented from others for use in connection with utility operations is subleased, the revenue derived from such subleasing shall be credited to the rent revenue account in operating revenues; provided, however, that in case the rent was charged to a clearing account, amounts received from subleasing the property shall be credited to such clearing account.

- The cost, when incurred by the lessee, of operating and maintaining leased property, shall be charged to the accounts appropriate for the expense if the property were owned.
- The cost incurred by the lessee of additions and replacements to electric plant leased from others shall be accounted for as provided in electric plant instruction.

Attachment B: NoLoad Calculation Examples

The information included in this Attachment B provides guidance for calculating No-Load Costs for various types of generating units.

B.1 No-Load Fuel

All Market Sellers shall use No-Load Fuel to develop No-Load Costs for their units. Since generating units cannot normally be run stable at zero net output, the no-load fuel may be determined by:

Collecting heat input values as a function of output and performing a regression analysis,

Using heat input values as provided by OEM and performing a regression analysis,

Using the initial design heat input curve for an immature unit and performing a regression analysis

Determining the measured value of fuel consumed at zero net output from test data (moment of generator output breaker closure).

B.2 Typical Steam Unit Example

An example of collecting heat input values as a function of unit's output and performing a regression analysis on the data to obtain the no-load fuel for a typical fossil steam unit is shown below:

Each diamond in the graph above indicates one hourly heat input data point calculated from plant instrumentation during operations. A regression analysis was performed on the data collected to obtain the unit's Heat Input curve as a function of unit's output with oil as a fuel:

$$\text{Heat Input (MMBtu / Hr)} = 0.00156391 * MW^2 + 9.6894 * MW + 306.744$$

Then the No-Load Fuel at zero output is

$$\text{No-load Fuel} = 306.744 \text{ MMBtu / Hr}$$

The initial estimate of a unit's **No-Load Cost (\$/Hr)** is:

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = \$14.00 MMBtu

$$\begin{aligned} \text{No Lad Cost} \left(\frac{\$}{\text{Hour}} \right) &= (\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC}) \\ &= 306.744 \frac{\text{MMBtu}}{\text{hr}} * 1.02 * \frac{\$14.00}{\text{MMBtu}} = \frac{\$4,380}{\text{hr}} \end{aligned}$$

The unit's Cost Curve must be developed to determine if adjustments are needed for the unit's No-Load Cost. The Heat Input Curve Equation is used to determine the units heat input at various outputs. Total Operating Cost is calculated by:

VOM = \$0.15/MMBtu

$$\text{Total Operating Cost} \left(\frac{\$}{\text{hr}} \right) = \text{Heat Input} * \text{Performance Factor} * (\text{TFRC} + \text{VOM})$$

Output (MW)	Heat Input (MMBtu/hr)	Total Operating Cost (\$/hr)
50	795.12	11,476
160	1897.08	27,381
310	3460.75	49,949
410	4542.29	65,559
525	5824.73	84,068
550	6109.00	88,171

The unit's Incremental Cost (\$/MWh) at various outputs can be determined arithmetically by the following equation:

$$\text{Incremental Cost} \left(\frac{\$}{\text{MWh}} \right) = \text{Total Operating Cost MW2} - \frac{\text{Total Operating Cost MW1}}{(\text{MW2} - \text{MW1})}$$

Output (MW)	Incremental Cost (\$/MWh)
50	141.91
160	144.59
310	150.46
410	156.10
525	160.95
550	164.11

When calculating the first increment, MW1 is zero and the Total Operating Cost MW1 is the No-Load Cost. Since the Incremental Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

The unit's Incremental Cost (\$/MWh) at various output levels can also be determined by using the derivative of the Heat Input Curve:

$$\begin{aligned} \text{Incremental Cost} \left(\frac{\$}{\text{MWh}} \right) \\ = (2 * 0.00156391 * \text{MW} + 9.6894) * \text{PerformanceFactor} * (\text{TFRC} + \text{VOM}) \end{aligned}$$

Output (MW)	Incremental Cost (\$/MWh)
50	142.10
160	147.07
310	153.84
410	158.36
525	163.55
550	164.68

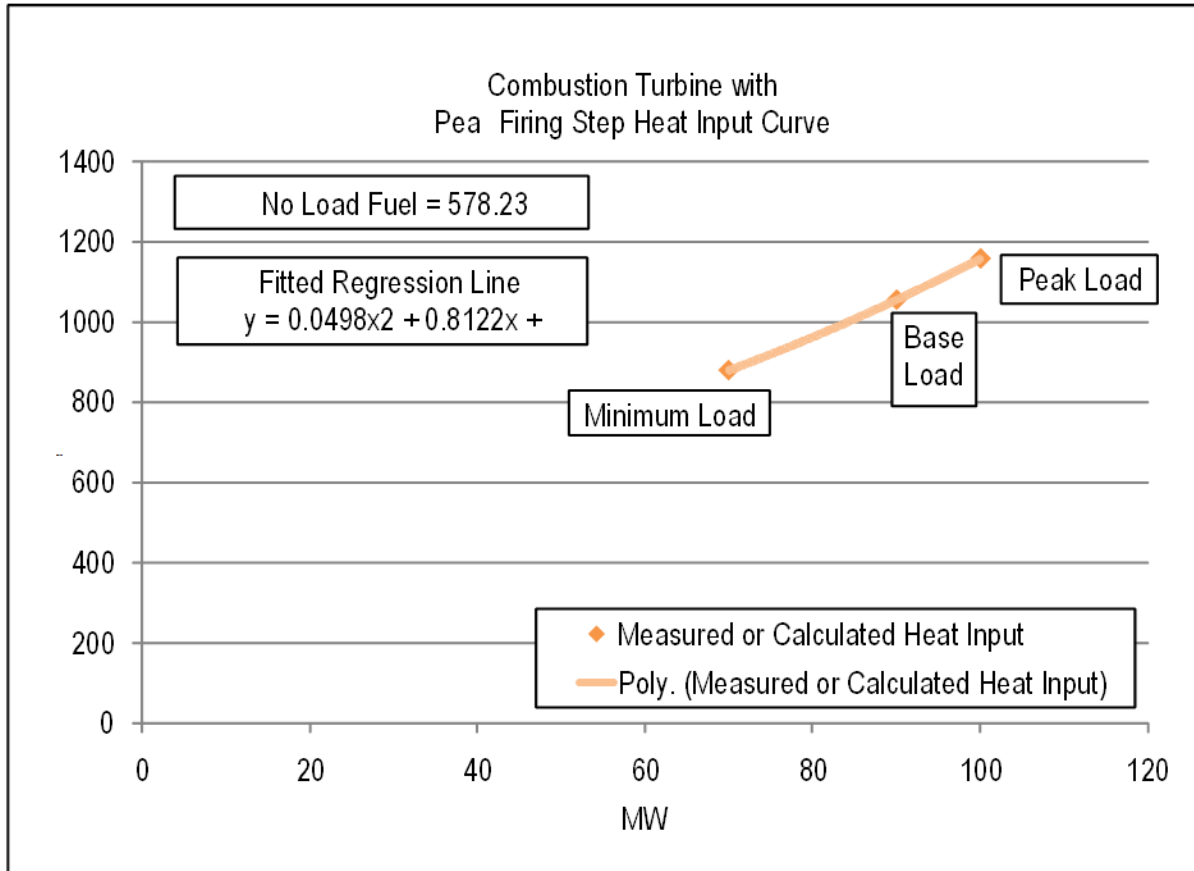
The No-Load Cost is calculated by subtracting the incremental cost (unit's economic minimum cost-offer value multiplied by MW value) at the unit's economic minimum point from the total cost (from the heat input at economic minimum value) at the unit's economic minimum point.

$$\begin{aligned}
 & \text{No-Load} \left(\frac{\$}{\text{hr}} \right) \\
 &= (\text{Economic Minimum Heat Input} * \text{Performance Factor} * (\text{TRFC} + \text{VOM})) \\
 &\quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 &= (795.12 \text{ MMBtu} / \text{hr} * 1.02 * (\$14.00 / \text{MMBtu} + \$0.15 / \text{MMBtu})) \\
 &\quad - (\$142.10 / \text{MWh} * 50 \text{ MW}) = \$4,370.97 \div \text{hr}
 \end{aligned}$$

Differences in the calculated No-Load Cost between the two methods are due to the differences in using a block average cost offer method versus a sloped derivative cost offer. When using the derivative method, user must select "Use Sloped Offer" when entering cost information into Markets Gateway.

B.3 Typical Combustion Turbine Example

An example of using the design heat input curve and performing a regression analysis to obtain the no-load fuel for a simple cycle CT with peak firing is shown below:



Each diamond in the graph above is a design heat input data point obtained from the original equipment manufacturer or calculated by heat balance. A regression analysis was performed on the design data to obtain the unit's Heat Input curve as a function of unit's output with natural gas as a fuel:

Heat Input (MMBtu/Hr) =

$$0.0498 * MW^2 + 0.8122 * MW + 578.23$$

Then the No-Load Fuel at zero output is:

$$\text{No-Load Fuel} = 578.23 \text{ MMBtu / hr}$$

The initial estimate of a unit's **No-Load Cost (\$/Hr)** is:

Performance Factor = 1.02

Total Fuel Related Cost (TFRC) = \$4.00/MMBtu

$$\begin{aligned} \text{No Load Cost} (\$/hr) &= (\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC}) \\ &= 578.23 \text{ MMBtu / hr} * 1.02 * \$4.00 / \text{MMBtu} = \$2,359 / \text{hr} \end{aligned}$$

The unit's Cost Curve must be developed to determine if adjustments are needed for the unit's No-Load Cost. The Heat Input Curve Equation is used to determine the unit's heat input at various unit output levels. Total Operating Cost is calculated by:

Maintenance Factor = 1.0 for Minimum & Base (= 3.0 for Peak)

VOM = \$75.00/ESH

$$\begin{aligned} & \text{Total Operating Cost} (\$/hr) \\ & = \text{Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{Maintenance Factor} * \text{VOM} \end{aligned}$$

Output (MW)	Heat Input (MMBtu/hr)	Total Operating Cost (\$/hr)
70	879.02	3,662
90	1054.57	4,378
100	1157.28	5,022

The unit's Incremental Cost (\$/MWh) at various unit output levels can be determined arithmetically by the following equation:

$$\begin{aligned} & \text{Incremental Cost} (\$/MWh) \\ & = \left(\frac{\text{Total Operating Cost MW2} - \text{Total Operating Cost MW1}}{\text{MW2} - \text{MW1}} \right) \end{aligned}$$

Output (MW)	Incremental Cost (\$/MWh)
70	18.61
90	35.82
100	64.42

When calculating the first increment, MW1 is zero and the Total Operating Cost MW1 is the No-Load Cost. Since the Incremental Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

The unit's Incremental Cost (\$/MWh) at various unit output levels can also be determined by using the derivative of the Heat Input Curve:

$$\begin{aligned} & \text{Incremental Cost} (\$/MWh) \\ & = ((2 * 0.0498 * \text{MW} + 0.8122) * \text{Performance Factor} * \text{TFRC}) + \frac{\Delta \text{VOM}}{\Delta \text{MW}} \end{aligned}$$

Since VOM is in the units of \$/hr it can only be added to the first incremental and any incremental where the maintenance factor changes.

Output (MW)	Incremental Cost (\$/MWh)
70	32.83
90	39.89
100	66.45

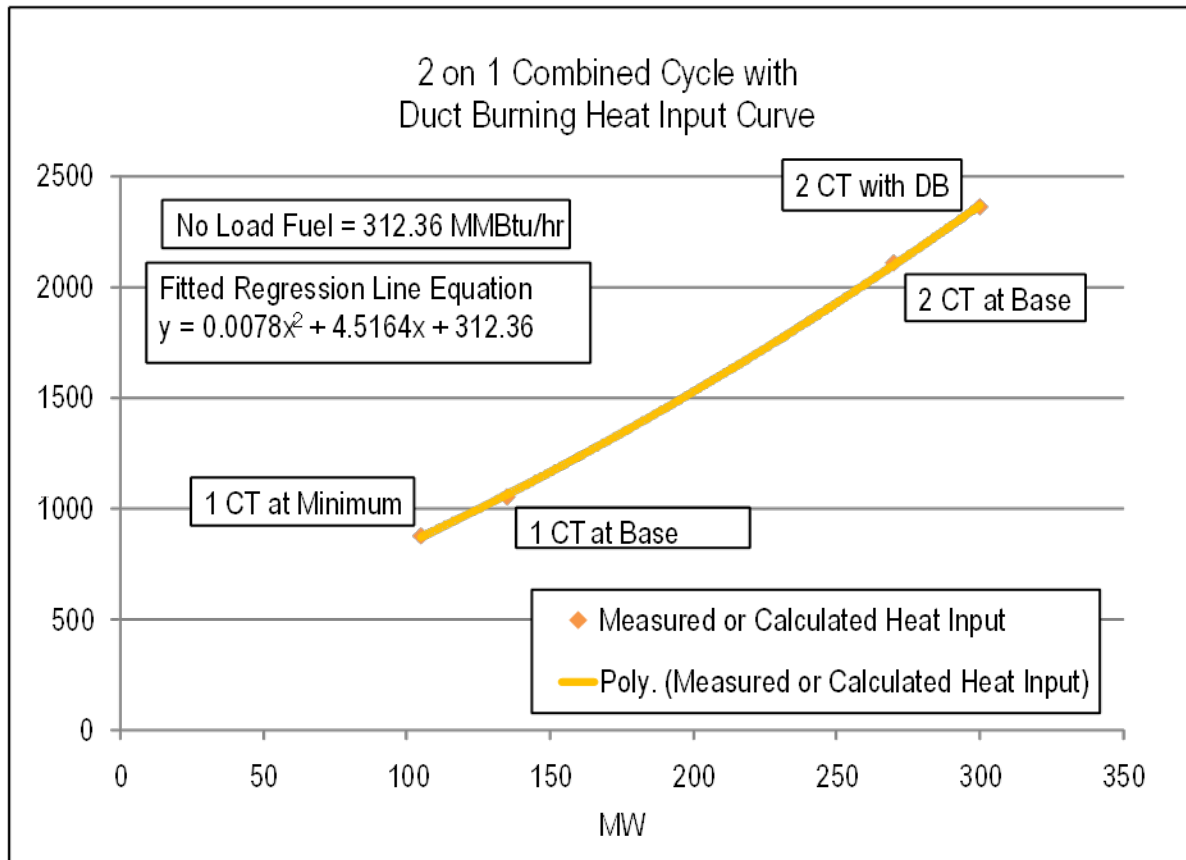
The No-Load Cost is calculated by subtracting the incremental cost (unit's economic minimum cost-offer value multiplied by MW value) at the unit's economic minimum point from the total cost (from the heat input at economic minimum value) at the unit's economic minimum point.

$$\begin{aligned}
 & \text{No-Load Cost ($ / hr)} \\
 & = (\text{Economic Minimum Heat Input} * \text{Performance Factor} * \text{TFRC}) \\
 & + \text{VOM} - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 & = (879.02 \text{ MMBtu} / \text{hr} * 1.02 * \$4.00 / \text{MMBtu}) \\
 & + (\$75.00 / \text{ESH}) - (\$32.83 / \text{MWh} * 70 \text{ MW}) = \$1,363.30 / \text{hr}
 \end{aligned}$$

Differences in the calculated No-Load Cost between the two methods are due to the differences in using a block average cost offer method versus a sloped derivative cost offer. When using the derivative method, user must select "Use Sloped Offer" when entering cost information into Markets Gateway.

B.4 Typical 2 on 1 Combined Cycle with Duct Burning Example

An example of using the design heat input curve and performing a regression analysis of the data to obtain the no-load fuel for a two on one CC with duct burners is shown below:



Each diamond in the graph above is a design heat input data point obtained from the original equipment manufacturer or calculated by heat balance. A regression analysis was performed on the design data to obtain the unit's Heat Input curve as a function of unit output levels with natural gas as a fuel:

$$\text{Heat Input (MMBtu / Hr)} = 0.0078 * \text{MW}^2 + 4.5164 * \text{MW} + 312.36$$

Then the No-Load Fuel at Zero output is:

$$\text{No-Load Fuel} = 312.36 \text{ MMBtu / hr}$$

The initial estimate of a unit's **No-Load Cost (\$/hr)** is:

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = \$4.00/MMBtu

$$\begin{aligned} \text{No Load Cost (\$/hr)} &= \\ &(\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC}) \\ &= 312.36 \text{ MMBtu / hr} * 1.02 * \$4.00 / \text{MMBtu} = \$1,274 / \text{hr} \end{aligned}$$

The unit's Cost Curve must be developed to determine if adjustments are needed for the unit's No-Load Cost. The Heat Input Curve Equation is used to determine the units heat input at various unit output levels. Total Operating Cost is calculated by:

Maintenance Factor = 1.0

VOM = \$75.00/ESH

$$\begin{aligned} & \text{Total Operating Cost (\$/hr)} \\ & = \text{Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{Maintenance Factor} * \text{VOM} \end{aligned}$$

Output (MW)	Heat Input (MMBtu/hr)	Total Operating Cost (\\$/hr)
105	872.58	3,635
135	1064.23	4,417
270	2100.41	8,720
300	2369.28	9,817

The unit's Incremental Cost (\$/MWh) at various unit output levels can be determined arithmetically by the following equation:

$$\begin{aligned} & \text{Incremental Cost (\$/MWh)} = \\ & \text{Total Operating Cost MW2} - \frac{\text{Total Operating Cost MW1}}{(\text{MW2} - \text{MW1})} \end{aligned}$$

Output (MW)	Incremental Cost (\$/MWh)
105	22.48
135	26.06
270	31.87
300	32.72

When calculating the first increment, MW1 is zero and the Total Operating Cost MW1 is the No-Load Cost. Since the Incremental Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

The unit's Incremental Cost (\$/MWh) at various unit output levels can also be determined by using the derivative of the Heat Input Curve:

$$\begin{aligned} & \text{Incremental Cost (\$/MWh)} = \\ & ((2 * 0.0078 * \text{MW} + 4.5164) * \text{Performance Factor} * \text{TFRC}) + \Delta \text{VOM} / \Delta \text{MW} \end{aligned}$$

Since VOM is in the units of \$/hr it can only be added to the first incremental and any incremental where the maintenance factor changes.

Output (MW)	Incremental Cost (\$/MWh)
105	25.82

Output (MW)	Incremental Cost (\$/MWh)
135	27.02
270	36.17
300	37.52

The No-Load Cost is calculated by subtracting the incremental cost (unit's economic minimum cost-offer value multiplied by MW value) at the unit's economic minimum point from the total cost (from the heat input at economic minimum value) at the unit's economic minimum point.

$$\begin{aligned}
 & \text{NO-Load Cost} (\$/hr) \\
 & = \text{Economic Minimum Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{VOM} \\
 & - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 & = (872.58 \text{ MMBtu/hr} * 1.02 * \$4.00 / \text{MMBtu}) + (\$75.00 / \text{ESH}) \\
 & - (\$25.82 / \text{MWh} * 105 \text{ MW}) = \$924.03 / \text{hr}
 \end{aligned}$$

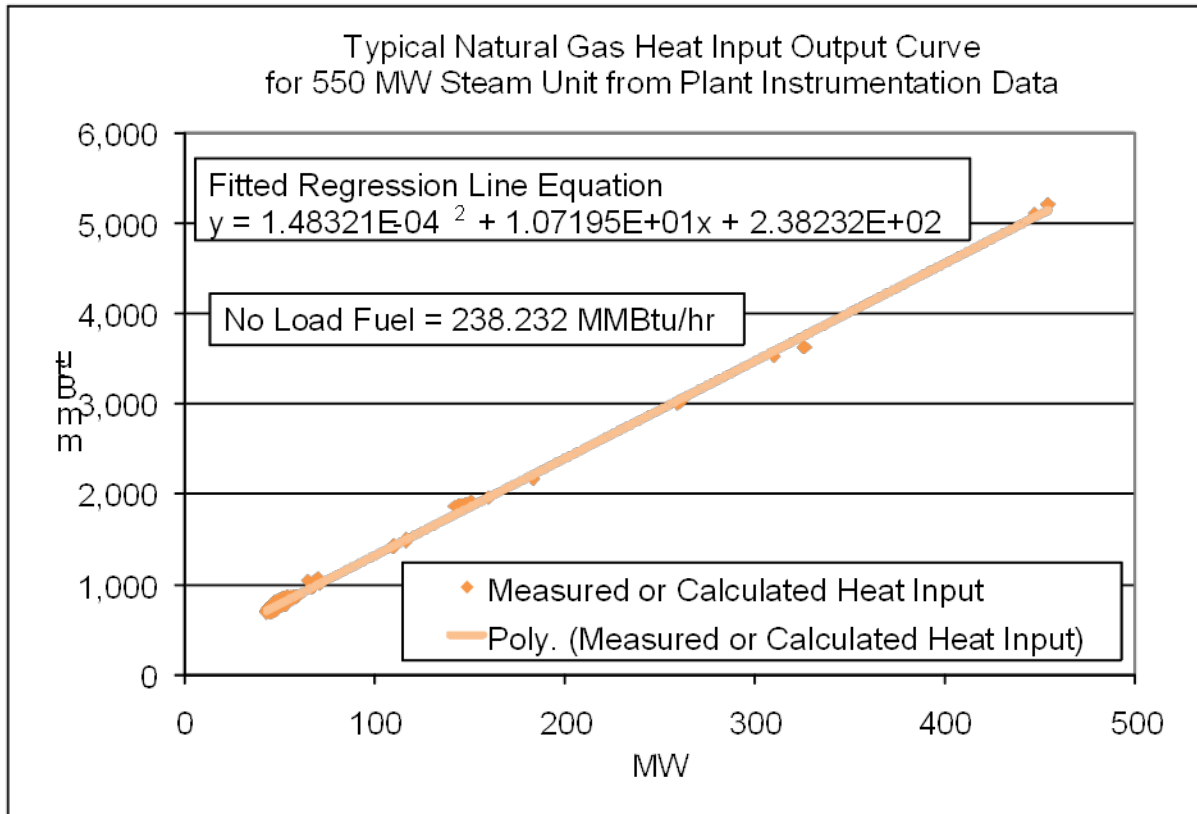
Since VOM is in the units of \$/hr it can only be added to the first incremental and any incremental where the maintenance factor changes.

Differences in the calculated No-Load Cost between the two methods are due to the differences in using a block average cost offer method versus a sloped derivative cost offer. When using the derivative method, user must select "Use Sloped Offer" when entering cost information into Markets Gateway.

B.5 No-Load Cost Adjustments

The calculated No-Load Cost may need to be adjusted to allow for the first incremental point of the unit's generator offer curve to comply with PJM's monotonically increasing curve requirement.

An example of adjusting the No-Load Cost for a typical natural gas fired Steam Unit after calculation is as follows. Heat input values as a function of various unit output levels were collected for a typical fossil steam and a regression analysis was performed to obtain the No-Load Cost.



Each diamond in the graph above indicates one hourly heat input data point calculated from plant instrumentation during operations. A regression analysis was performed on the data collected to obtain the unit's Heat Input curve as a function of various unit output levels with oil as a fuel:

$$\text{Heat Input (MMBtu/hr)} = 0.000148321 * MW^2 + 10.7195 * MW + 238.232$$

Then the No-Load Fuel at zero output is:

$$\text{No Load Fuel} = 238.232 \text{ MMBtu/hr}$$

The initial estimate of a unit's **No-Load Cost (\$/Hr)** is:

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = \$4.00/MMBtu

$$\begin{aligned} \text{No Load Cost (\$/hr)} &= (\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC}) \\ &= 238.232 \text{ MMBtu/hr} * 1.02 * \$4.00 / \text{MMBtu} = \$972 / \text{hr} \end{aligned}$$

The unit's Cost Curve must be developed to determine if adjustments are needed for the unit's No-Load Cost. The Heat Input Curve Equation is used to determine the units heat input at various unit output levels. Total Operating Cost is calculated by:

VOM = \$0.15/MMBtu

$$\text{Total Operation Cost (\$/hr)} = (\text{Heat Input} * \text{Performance Factor} * (\text{TFRC} + \text{VOM}))$$

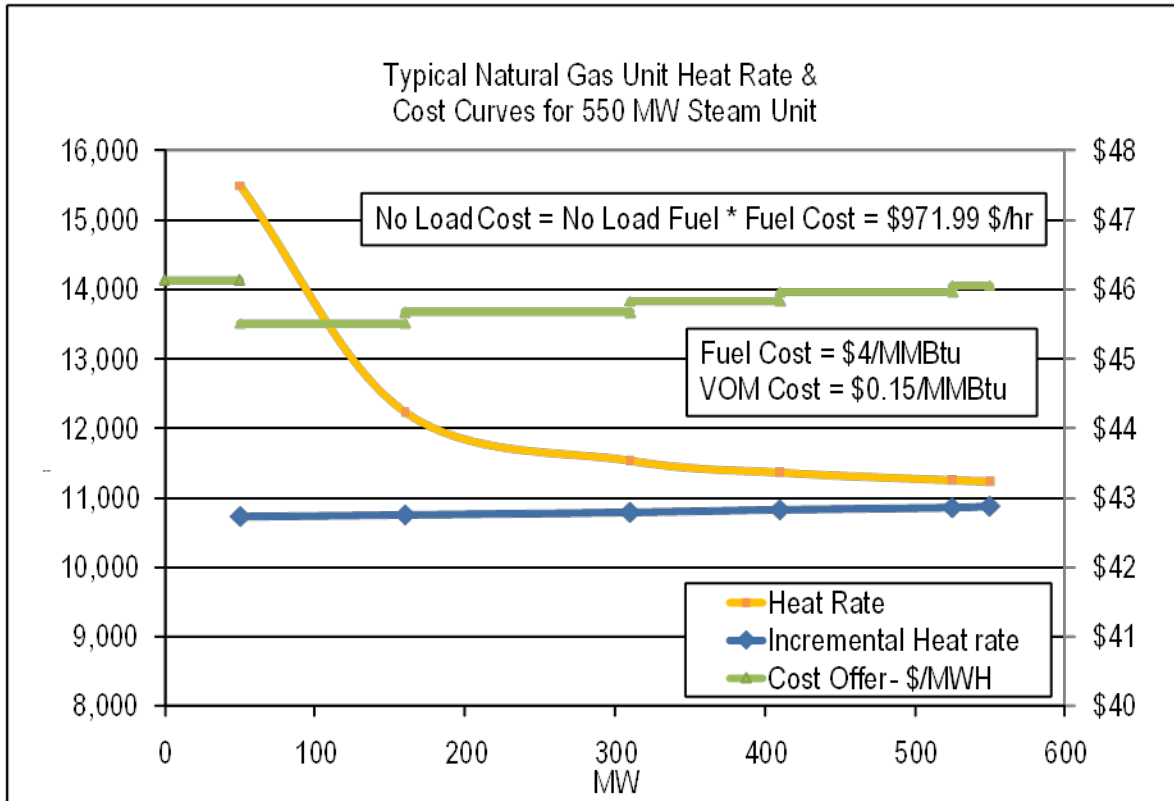
Output (MW)	Heat Input (MMBtu/hr)	Total Operating Cost (\\$/hr)
50	774.58	3,279
160	1957.15	8,285
310	3575.53	15,135
410	4658.16	19,718
525	5906.85	25,004
550	6178.82	26,155

The unit's Incremental Cost (\\$/MWh) at various unit output levels can be determined arithmetically by the following equation:

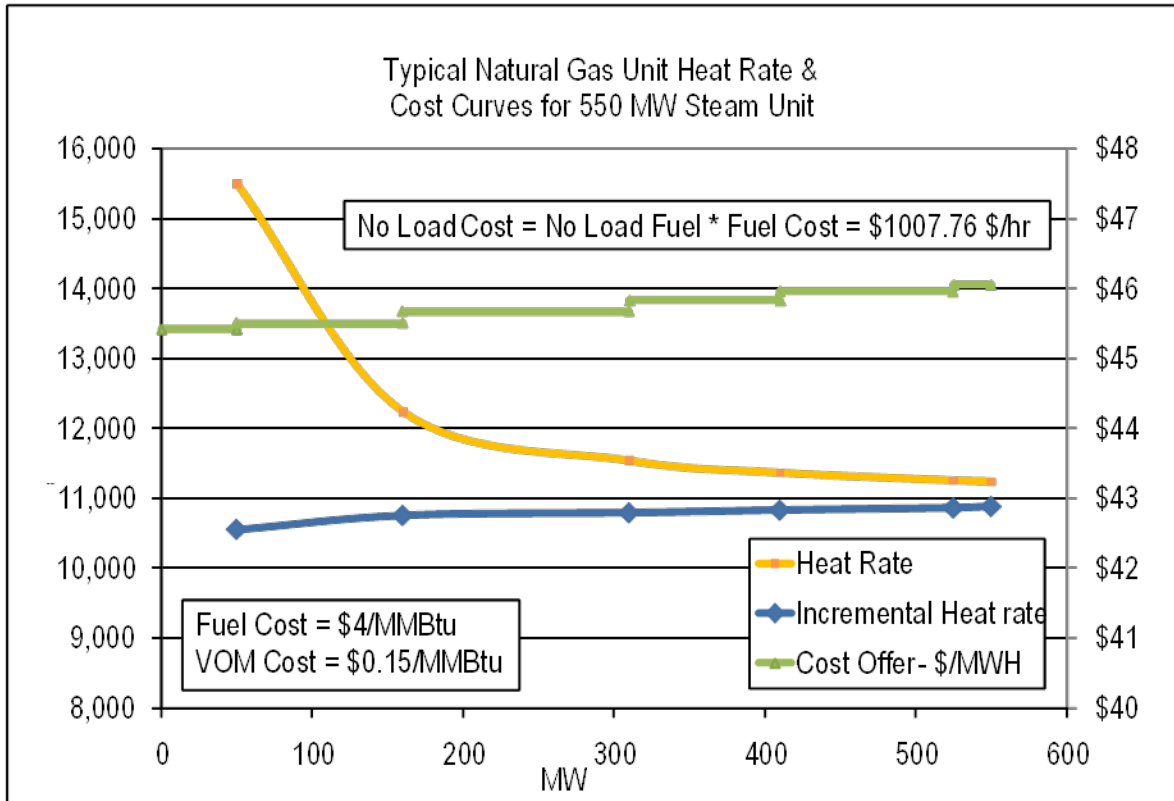
$$\text{Incremental Cost (\$/MWh)} = \frac{\text{Total Operating Cost MW2} - \text{Total Operating Cost MW1}}{\text{MW2} - \text{MW1}}$$

Output (MW)	Incremental Cost (\\$/MWh)
50	46.14
160	45.51
310	45.67
410	45.83
525	45.96
550	46.05

When calculating the first increment, MW1 is zero and the Total Operating Cost MW1 is the No-Load Cost. However due to the quality of the heat input data, the first increment of the cost offer was greater than the second increment. This is shown in the graph below:



The No-Load Cost was then raised to \$1007.76 until the first increment of the cost offer was less than \$1/MWh below the second increment, producing a monotonically increasing curve in the graph below:



To avoid making adjustments to the No-Load Cost, first calculate the unit’s Incremental Cost (\$/MWh) at various outputs using the derivative of the Heat Input Curve:

$$\text{Incremental Cost (\$/MWh)} = (2 * 0.000148321 * \text{MW} + 10.7195) * \text{Performance Factor} * (\text{TFRC} + \text{VOM})$$

Output (MW)	Incremental Cost (\$/MWh)
50	45.43
160	45.58
310	45.76
410	45.89
525	46.03
550	46.06

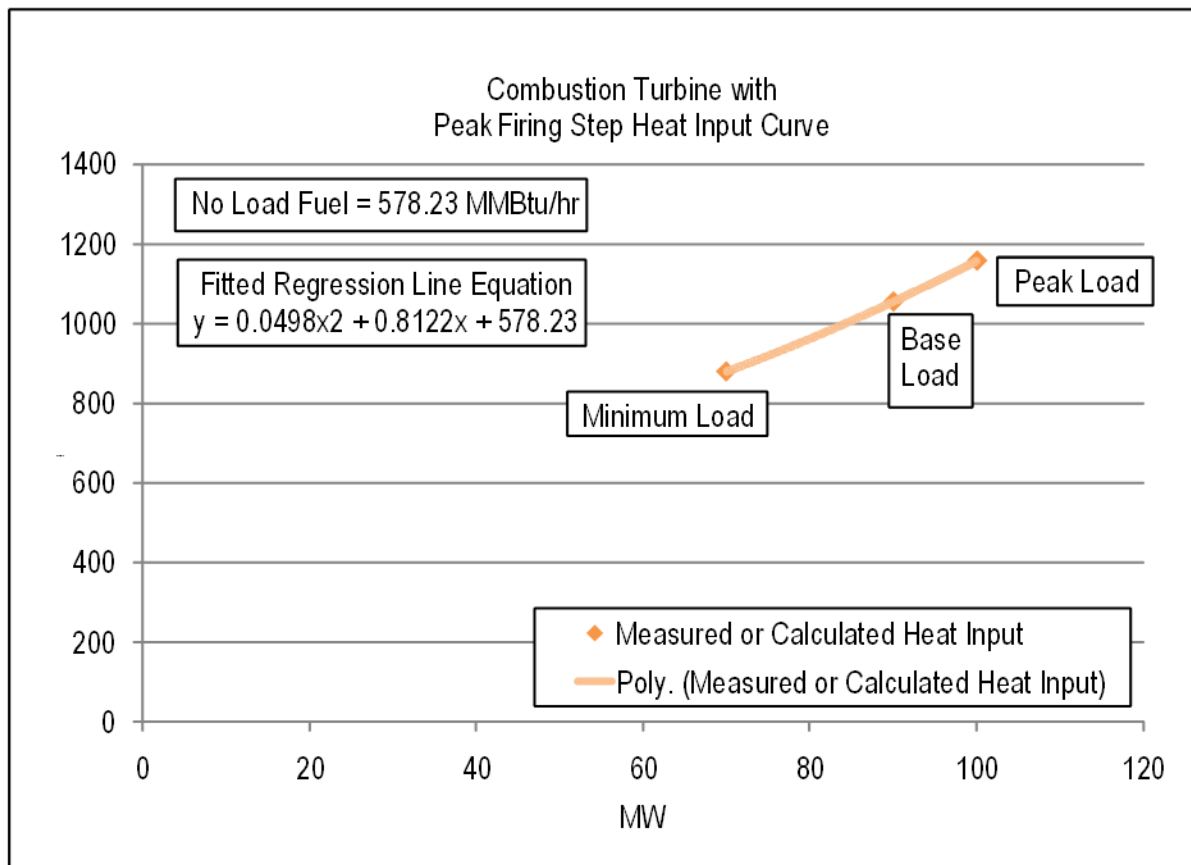
The No-Load Cost is calculated by subtracting the incremental cost (unit’s economic minimum cost-offer value multiplied by MW value) at the unit’s economic minimum point from the total cost (from the heat input at economic minimum value) at the unit’s economic minimum point.

$$\begin{aligned}
 & \text{No-Load Cost (\$ / hr)} \\
 & = (\text{Economic Minimum Heat Input} * \text{Performance Factor} * (\text{TFRC} + \text{VOM})) \\
 & \quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 & = (774.58 \text{ MMBtu / hr} * 1.02 * (\$4.00 / \text{MMBtu} + \$0.15 / \text{MMBtu})) - (\$45.43 / \text{MWh} * 50 \text{ MW}) = \$1007.3 / \text{hr}
 \end{aligned}$$

Differences in the calculated No-Load Cost between the two methods are due to the differences in using a block average cost offer method versus a sloped derivative cost offer. When using the derivative method, user must select “Use Sloped Offer” when entering cost information into Markets Gateway.

B.6 Combustion Turbine Zero No-Load Example

A zero No-Load example for a simple cycle combustion turbine with a single offer block is shown below:



Each diamond in the graph above is a design heat input data point obtained from the original equipment manufacturer or calculated by heat balance. A regression analysis can be performed on the design data to obtain the unit’s Heat Input curve as a function of various unit output levels with natural gas as a fuel:

$$\text{Heat Input (MMBtu / Hr)} =$$

$$0.0498*MW^2 + 0.8122*MW + 578.23$$

Or the fuel input to the unit during operation can be directly measured.

The unit may be submitted with a single cost offer block and zero No-Load Cost (\$/Hr).

No-Load Cost (\$/Hr) = \$0/hr

The unit's Heat Input Curve Equation or actual measured fuel input data is used to determine the units heat input at its maximum output (100MW).

Heat Input (MMBtu/Hr) =

$$0.0498*MW^2 + 0.8122*100 + 578.23$$

$$0.0498* 100^2 + 0.8122*100 + 578.23 = 1157.28 \text{ MMBtu} / \text{hr}$$

Total Operating Cost at 100 MW is calculated by:

Maintenance Factor = 1.0 for Minimum & Base (=4.0 for Peak)

VOM = \$75.00/ESH

Total Operating Cost (\$/hr) =

$$\text{Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{Maintenance Factor} * \text{VOM}$$

$$= 1157.28 \text{ MMBtu} / \text{hr} * 1.02 * \$4.00 / \text{MMBtu} + 4.0 * \$75 / \text{hr} = \$5,022 / \text{hr}$$

The unit's Incremental Cost (\$/MWh) at maximum output with a zero No-Load Cost is calculated by:

Incremental Cost (\$/MWh) =

$$\text{Total Operating Cost} / \text{Maximum Output}$$

$$= (\$5,022 / \text{hr}) / (100\text{MW}) = \$50.22 / \text{MWh}$$

Revision History

Revision 35 (04/24/2020):

- Section 12:
 - Update to reflect suspension of PJM Opportunity Cost Calculator
 - Update Independent Market Monitor Opportunity Cost Calculator methodology

Revision 34 (02/11/2020):

- Conforming VOM adder format rules to FERC Dockets ER19-210 and EL19-8

Revision 33 (12/03/2019):

- FERC Order 841 Energy Storage Resources changes:
 - Section 11 – Batteries and Flywheels
- Equation clarified in Section 7.3
- Changes were approved by PJM Board on December 4, 2019

Revision 32 (05/13/2019):

- FERC VOM Order Docket No. ER19-210-001 conforming changes:
 - Sections 2.3, 2.6, 3.6, 4.6, 5.6, 6.6, 7.6, 9.6
- Revised Exhibit 1: Handy Whitman Index to reflect figures for the year 2019

Revision 31 (02/15/2019):

- Incorporate Independent Market Monitor Opportunity Cost Calculator methodology

Revision 30 (12/04/2018):

- Biennial Review

Revision 29 (5/15/2017):

- Fuel Cost Policy and Hourly Offers conforming changes:
 - Section 1.8, 2.3, 2.3.1, 2.3.1.1, 2.3.1.2, 2.3.1.3
- Additional changes to require submission to PJM and MMU
- Removed references to Manual 35 as this has been retired

Revision 28 (10/18/2016):

Biennial Review and Administrative Changes:

- Unit Owner changed to Market Seller
- Capitalization, Abbreviations, Grammar
- Pumped Storage Hydro

- Demand Resource

Revision 27 (04/20/2016):

Administrative Changes:

- Updated references eMKT to Markets Gateway
- Operating Parameter Definition Updates

Revision 26 (11/05/2014):

- Correct Mileage Ratio in Section 2.8 to Mileage

Revision 25 (07/28/2014):

- Update to the Handy Whitman Index numbers chart in section 2.6.1

Revision 24 (03/01/2014):

- Cyclic peaking and starting factors for combined cycle and combustion turbines in sections 2.6.4, 4, 5, and 6 were updated to reflect how to use OEM values. A reference was added for extended cold start.

Revision 23 (08/01/2013):

- Regulation Cost Based Offer update shifting manual language from Manual 11 to Manual 15
- Updated Section 2.8 related to Regulation cost based offers and 11.8 for Energy Storage units and Regulation

Revision 22 (06/01/2013):

- Update to the Handy Whitman Index numbers chart in section 2.6.1

Revision 21 (04/01/2013):

- Added sections for hydro, energy storage, wind, solar and biofuel powered generation resources.
- Added shutdown cost language for DSR resources participating in synchronous reserve.
- Modified the Cost Development and Approval process to include more than generation resources.

Revision 20 (11/01/2012):

- Added section 2.6.5 to define maintenance cost calculation for immature units
- Updated Long Term Maintenance Cost language for Combustion Turbines and Combined Cycles for additional clarity

Revision 19 (06/01/2012):

- Updated Handy Whitman Index with actual for 2011 and estimate for 2012.

Revision 18 (02/08/2012):

- Removes overhaul costs for Combined Cycles and (CCs) Combustion Turbines (CTs) from Variable Operation and Maintenance Cost (VOM). *Section 5.6, 5.6.2 and 6.2*
- Adds clarity to the development of No Load Costs. *Section 1.7.3, 2.1 and Attachment B*
- Updates Manual 15 to be consistent with the tariff with respect to Non-Regulatory and Energy Market Opportunity Costs. *Section 9*

Revision 17 (06/01/2011): Handy Whitman Update

- Section 2.6.1, Exhibit 1: Updated Handy Whitman Index Numbers for the year 2011.
- Section 9: Opportunity Cost Guideline is updated per the informational filing submitted by PJM on May 12, 2011, in Docket No. EL08-47-005.

Revision 16 (04/06/2011): Rewrite of entire Manual 15

- This revision improves readability and addresses changes as a result of FERC Order 719 (Docket Nos. ER09-1063-000 and ER09-1063-001) requirements).

Revision 15 (10/27/2010):

- Modifies Section 8: Opportunity Cost Guidelines to conform to FERC Order EL08-47-005 allowing for the inclusion of Opportunity Costs for Energy or Environmental Limitation

Revision 14 (06/01/2010):

- Section 5: Updated Chronology of Maintenance Adder Escalation Index Numbers for the year 2010.

Revision 13 (05/07/2010):

- Section 5: Updated Maintenance Period for the choice of 20 years or 10 years and added Unit Configuration Addition Maintenance Adder language

Revision 12 (02/23/2010):

- Section 9: Updated Regulation Cost Guidelines approved 8/25/2009

Revision 11 (12/02/2009):

- Section 4: Updated Fuel Cost Policy Guidelines

Revision 10 (06/01/2009):

- Section 5: Updated Chronology of Maintenance Adder Escalation Index Numbers for the year 2009.

Revision 09 (01/23/2009):

- Section 4: Added CO₂ emission allowance cost to TFRC calculation. Updates to the TFRC cost equation reflect addition of CO₂ emission allowance cost.

- Section 5L: Updated Chronology of Maintenance Adder Escalation Index Numbers for the year 2008.
- Attachment A: TFRC equation updated to reflect addition of CO₂ emission allowance cost.

Revision 08 (10/16/2007):

- Exhibit 1 — Updated Chronology of Maintenance Adder Escalation Index Numbers for the year 2007.
- Section 9 — Modified the components of cost to supply Regulation Service.

Revision 07 (08/03/2006):

- Exhibit 1—Updated to include the new Manual 30: Alternative Collateral Program.
- Section 4—Added definition for Total Fuel-Related Costs for Pumped Storage Hydro Plant Generation.
- Section 5—Added guidelines for Long Term Service Contract Cost Recovery.
- Exhibit 2—Updated Chronology of Maintenance Adder Escalation Index Numbers for the year 2006.
- Section 7—Modified terminology for Spinning Synchronized Reserve.

Revision 06 (03/02/2006):

- Added guidelines for no-load fuel costs for Combustion Turbines to Section 1 and Section 2.
- Added “Long Term Maintenance Expenses” definition for Combustion Turbine and Combined Cycle Plants to Section 5.
- Revisions were made on the following pages: 8, 9, and 20-22.

Revision 05 (08/18/2005):

- Updated Exhibit 1 to include new PJM Manuals.
- Updated Exhibit 2, Chronology of Maintenance Adder Escalation Index Numbers, for the year 2005.

Revision 04 (09/01/2004):

- Insert new section nine into the CDS Manual

Revision 03 (06/01/2004):

- Revised table "Chronology of Maintenance Adder Escalation Index Numbers" in Section 5 to reflect figures for the year 2004.
- Reformatted to reflect the new PJM format and style.
- Updated list of PJM Manuals to reflect title changes and additional Manuals

Revision 02 (06/01/2003):

- Revised table in Section 5.6, “Chronology of Maintenance Adder Escalation Index Numbers”, for the year 2003

Revision 01 (12/01/2002):

- This revision incorporates changes to Section 7: Spinning Cost Guidelines. These changes reflect the rules associated with the new PJM Spinning Reserve Market.

Revision 00 (12/01/2002):

- This revision is the preliminary draft of the PJM Manual for **Cost Development Guidelines (M-15)**. Prior to Revision 00 of this Manual, a document with this name existed under direction of the PJM Operating Committee. Revision 00 was the first issuance of this Manual under the approval of the PJM Board of Directors, pursuant to Schedule 2 of the Operating Agreement of the PJM Interconnection, L.L.C.