



Manual 15: Cost Development Guidelines



*Working to Perfect the Flow of Energy*

PJM Manual 15:  
Cost Development Guidelines

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Prepared by

Cost Development Subcommittee

## Section 1: Introduction

### 1.7.3 No Load Cost

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

~~No-load cost -- has been defined as the calculated cost per hour to run at zero net output. However, the calculated no load cost may have to be adjusted to ensure that the slope of the Generator Offer Curve is monotonically increasing. Therefore, the no-load cost is the cost needed to create the starting point of a monotonically increasing incremental cost curve. is the calculated cost per hour to run at zero net output. The calculated no-load cost may have to be adjusted to ensure that the slope of the Generator Offer Curve is monotonically increasing.~~

## Section 2: Policies for All Unit Types

### 2.5 No Load

#### 2.5.1 No-Load Definitions

~~No-load cost is the hourly fixed cost, expressed in \$/hr, needed required to create the starting point of a monotonically increasing incremental cost curve. It has been defined as the cost to run the generating unit at zero MW output.~~

#### 2.5.2 No-Load Fuel

~~All PJM members 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 heat input curve may be determined by collecting heat input values as a function of output and performing a regression analysis extrapolating the total heat input output curve to zero net output. The heat input values as a function of output may be either created from empirical data heat rate testing data or be the initial design heat input curve for an immature unit.~~

~~Therefore, No load fuel consumed shall be the theoretical value of fuel consumed at zero net output from test data or through extrapolation of the theoretical regression analysis of the input output curve. 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. All PJM Members shall use no load fuel consumed to develop no load costs for their units.~~

~~No load fuel value shall be the value used to develop no load costs. The fuel associated with unit no load may be a theoretical value extrapolated from other unit operating data, or may be the result of a specific test performed to document the no load fuel consumed. Sufficient documentation for each generating unit's no-load point in MBTUs (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. The MMU can verify calculation methods used subject to the Cost Methodology and Approval Process including the elements of Attachment B.~~

#### 2.5.32 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))

$$\text{No Load Cost}(\$/\text{ Hour}) =$$

$$(\text{ No Load Fuel} * \text{ Performance Factor} * \text{ TFRC})$$

should 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, the 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.

$$\text{No Load Cost}(\$/\text{ Hour}) =$$

$$(\text{ Economic Minimum Heat Input} * \text{ Performance Factor} * (\text{ TFRC} + \text{ VOM}))$$

$$- (\text{ Economic Minimum Incremental Cost} (\$/\text{MWH}) * \text{ Economic Minimum (MW)})$$

No-Load Fuel (MBTU/hour) is the total fuel to sustain zero net output MW at synchronous generator speed. Note that if the unit of VOM is in terms of dollars per Equivalent Service Hours (ESH), the equation changes to:

$$\text{No Load Cost}(\$/\text{ Hour}) =$$

$$(\text{ Economic Minimum Heat Input} * \text{ Performance Factor} * \text{ TFRC}) + \text{ VOM}$$

$$- (\text{ Economic Minimum Incremental Cost} (\$/\text{MWH}) * \text{ Economic Minimum (MW)})$$

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

## Attachment B: No Load 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 PJM members 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 Original Equipment Manufacturer and performing a regression analysis,

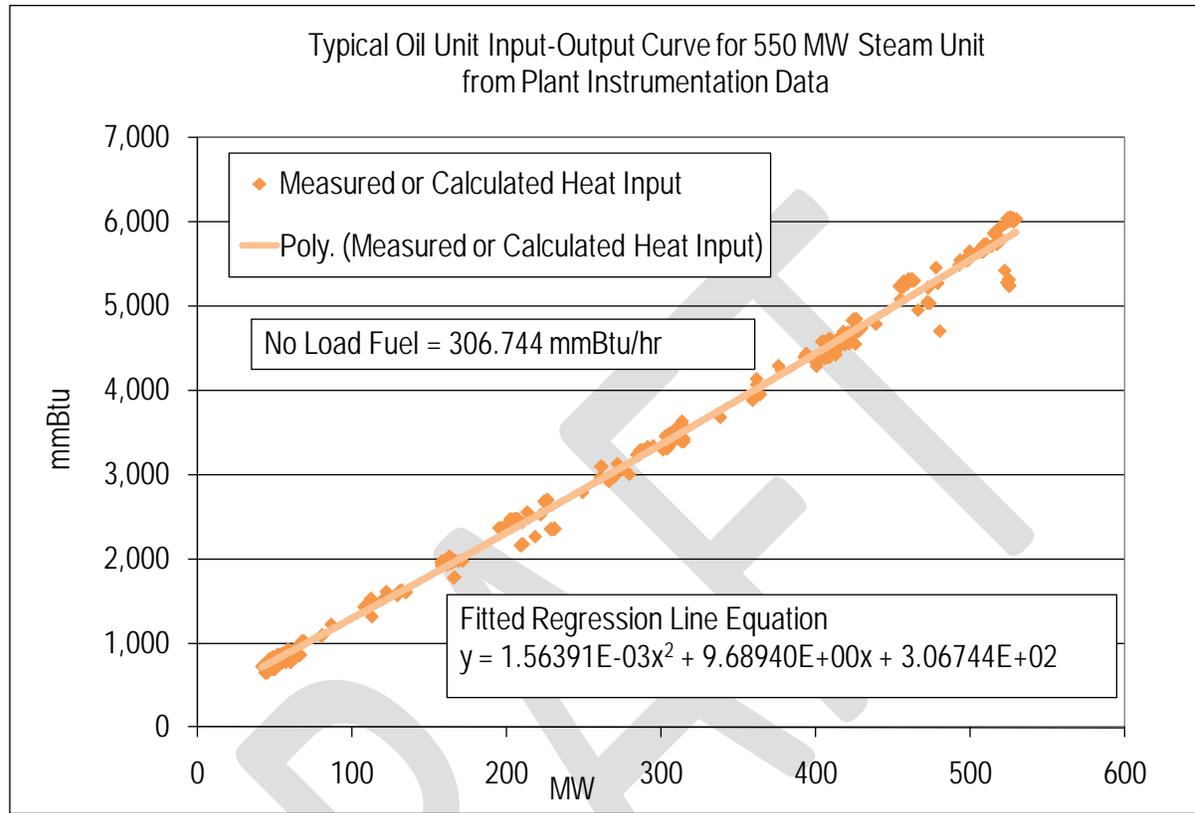
Using the initial design heat input curve for an immature unit and performing a regression analysis

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

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## B.2 Typical Steam Unit Example

An example of collecting heat input values as a function of 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 marker 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 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:

$$\text{No Load Cost}(\$/ \text{ Hour}) =$$

$$( \text{No Load Fuel} * \text{Performance Factor} * \text{TFRC} )$$

When assuming the Performance Factor = 1.02 and Total Fuel Related Cost (TFRC) = \$14.00 per mmBtu

$$\begin{aligned} & \text{No Load Cost} (\$ / \text{Hour}) \\ &= 306.744 \text{ mmBtu/hr} * 1.02 * \$14.00/\text{mmBtu} \\ &= \$4,380/\text{hr} \end{aligned}$$

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:

$$\begin{aligned} & \text{Total Operating Cost} (\$/\text{hr}) \\ &= \text{Heat Input} * \text{Performance Factor} * (\text{TFRC} + \text{VOM}) \end{aligned}$$

The VOM is assumed to be equal to \$0.15/mmBtu, then the Total Operating Cost (\$/hr) at 50 MW is:

$$\begin{aligned} & \text{Total Operating Cost} (\$/\text{hr}) \text{ at } 50 \text{ MW} \\ &= 795.12 \text{ mmBtu/hr} * 1.02 * (\$14.00/\text{mmBtu} + \$0.15/\text{mmBtu}) \\ &= \$11,476/\text{hr} \end{aligned}$$

The total operating costs at various outputs are shown in the table below:

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

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

$$\text{Incremental Block Average Cost (\$/MWh)} = \frac{\text{Total Operating Cost MW2} - \text{Total Operating Cost MW1}}{\text{MW2} - \text{MW1}}$$

The Incremental Block Average Cost for the first interval at 50 MW is calculated where MW2 = 50 MW, MW1 = 0 MW, Total Operating Cost at 50 MW = \$11,476/hr and the Total Operating Cost at No Load = \$4,380/hr:

$$\begin{aligned} \text{Incremental Block Average Cost (\$/MWh) at 50 MW} \\ &= (\$11,476/\text{hr} - \$4,380/\text{hr}) / (50 - 0) \\ &= \$141.91/\text{MWh} \end{aligned}$$

The incremental block average costs for other intervals are shown in the table below:

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

Since the Incremental Block Average Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

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

$$\text{Incremental Cost (\$/MWh)} = (2 * 0.00156391 * \text{MW} + 9.6894) * \text{Performance Factor} * (\text{TFRC} + \text{VOM})$$

The Incremental Cost (\$/MWh) at 50 MW is calculated:

$$\begin{aligned}
 & \text{Incremental Cost (\$/MWh)} \\
 & = (2 * 0.00156391 * 50 \text{ MW} + 9.6894) * 1.02 * (\$14.00/\text{mmBtu} + \$0.15/\text{mmBtu}) \\
 & = \$142.10/\text{MWh}
 \end{aligned}$$

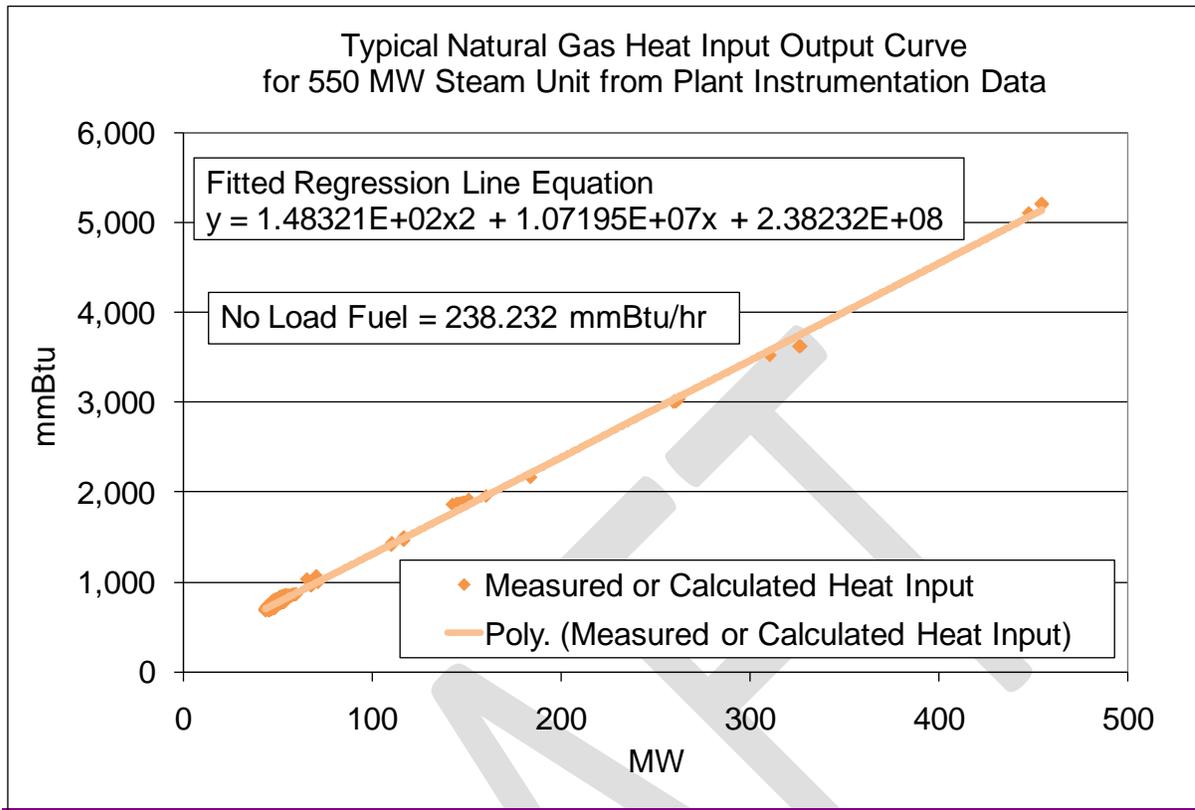
The incremental costs for other intervals are shown in the table below:

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

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.

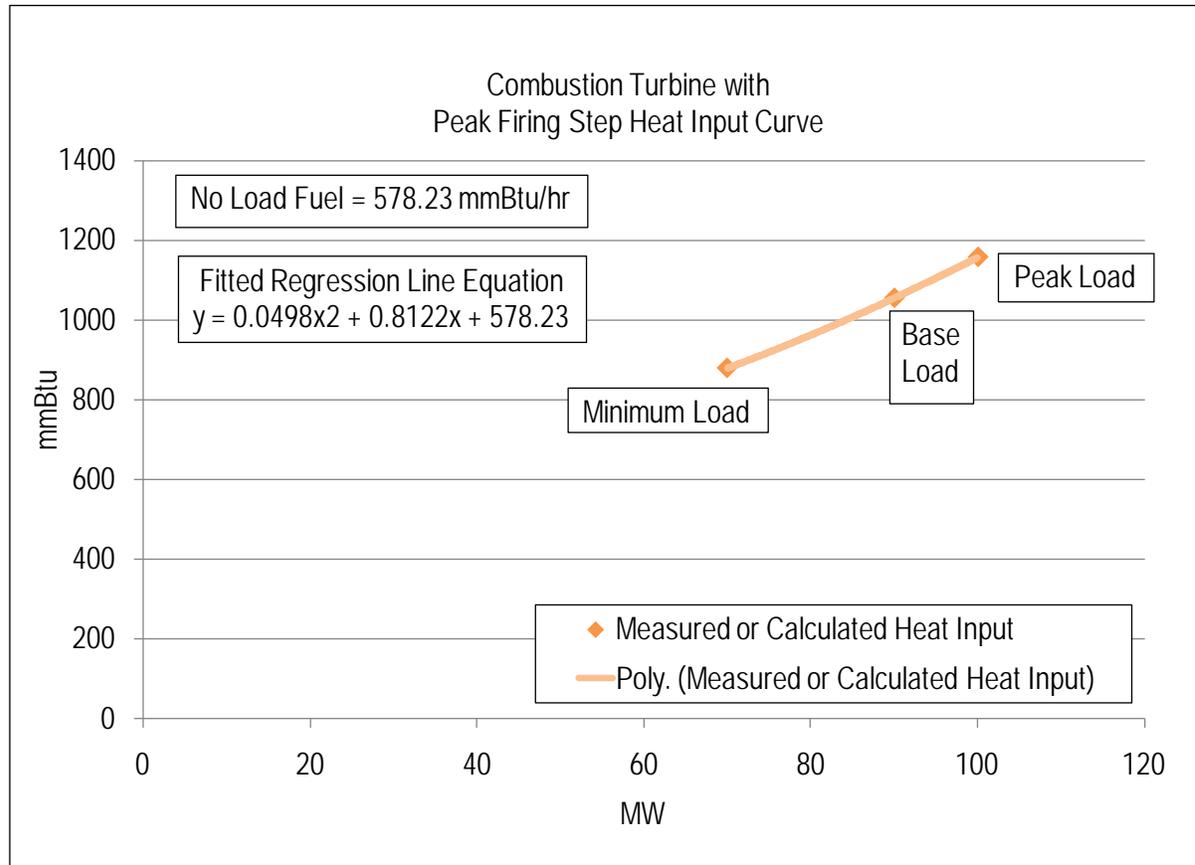
$$\begin{aligned}
 & \text{No – Load Cost (\$/hr)} \\
 & = (\text{Economic Minimum Heat Input} * \text{Performance Factor} * (\text{TRFC} + \text{VOM})) \\
 & \quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 & = (795.12\text{mmBtu/hr} * 1.02 * (\$14.00/\text{mmBtu}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

Differences in the calculated No-Load 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 block average method, the user cannot select "Use Offer Slope" when entering cost information into eMKT. When using the derivative method, user must select "Use Offer Slope" when entering cost information into eMKT.



### 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 combustion turbine with peak firing is shown below:



Each marker 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 Output with natural gas as a fuel:

$$\text{Heat Input (mmBTU/Hr)} = 0.0498 * MW^2 + 0.8122 * MW + 578.23$$

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:



$$\text{No Load Cost}(\$/\text{ Hour}) = \\ (\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC})$$

When assuming the Performance Factor = 1.02 and Total Fuel Related Cost (TFRC) = \$4.00 mmBtu

$$\begin{aligned} \text{No Load Cost}(\$/\text{ Hour}) \\ = 578.23\text{mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} \\ = \$2,359/\text{hr} \end{aligned}$$

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 units heat input at various outputs. Total Operating Cost is calculated by:

$$\begin{aligned} \text{Total Operating Cost} (\$/\text{hr}) \\ = \text{Heat Input} * \text{Performance Factor} * \text{TFRC} + (\text{Maintenance Factor} * \text{VOM}) \end{aligned}$$

The Maintenance Factor is assumed to be equal to 1.0 for Minimum & Base, 4.0 for Peak, and VOM is assumed to be equal to \$75.00/ESH, then the Total Operating Costs (\$/hr) at 70 MW is:

$$\begin{aligned} \text{Total Operating Cost} (\$/\text{hr})\text{at 70 MW} \\ = 879.02\text{mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} + (1.0 * \$75/\text{ESH}) \\ = \$3,662/\text{hr} \end{aligned}$$

The total operating costs at various outputs are shown below:

<u>Output (MW)</u>	<u>Heat Input (mmBtu/hr)</u>	<u>Total Operating Cost (\$/hr)</u>
<u>70</u>	<u>879.02</u>	<u>3,662</u>
<u>90</u>	<u>1054.57</u>	<u>4,378</u>
<u>100</u>	<u>1157.28</u>	<u>5,022</u>

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

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

The Incremental Block Average Cost for the first interval at 70 MW is calculated where MW2 = 70 MW, MW1 = 0 MW, Total Operating Cost at 70 MW = \$3,662/hr and the Total Operating Cost at No Load = \$2,359/hr:

$$\begin{aligned} \text{Incremental Block Average Cost (\$/MWh) at 70 MW} \\ &= (\$3,662/\text{hr} - \$2,359/\text{hr}) / (70 - 0) \\ &= \$18.61/\text{MWh} \end{aligned}$$

The incremental block average costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\\$/MWh)</u>
<u>70</u>	<u>18.61</u>
<u>90</u>	<u>35.82</u>
<u>100</u>	<u>64.42</u>

Since the Incremental Block Average Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

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

$$\begin{aligned} \text{Incremental Cost (\$/MWh)} = \\ ((2 * 0.0498 * \text{MW} + 0.8122) * \text{Performance Factor} * \text{TFRC}) + \Delta\text{VOM}/\Delta\text{MW} \end{aligned}$$

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. The Incremental Cost (\\$/MWh) at 70 MW is calculated:

$$\begin{aligned} \text{Incremental Cost (\$/MWh)} \\ = ((2 * 0.0498 * 70 \text{ MW} + 0.8122) * 1.02 * \$4.00/\text{mmBtu}) + \$75.00 / \text{ESH} / (70 \text{ MW} - 0 \text{ MW}) \end{aligned}$$

$$= \$32.83/\text{MWh}$$

The incremental costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\$/MWh)</u>
<u>70</u>	<u>32.83</u>
<u>90</u>	<u>39.89</u>
<u>100</u>	<u>66.45</u>

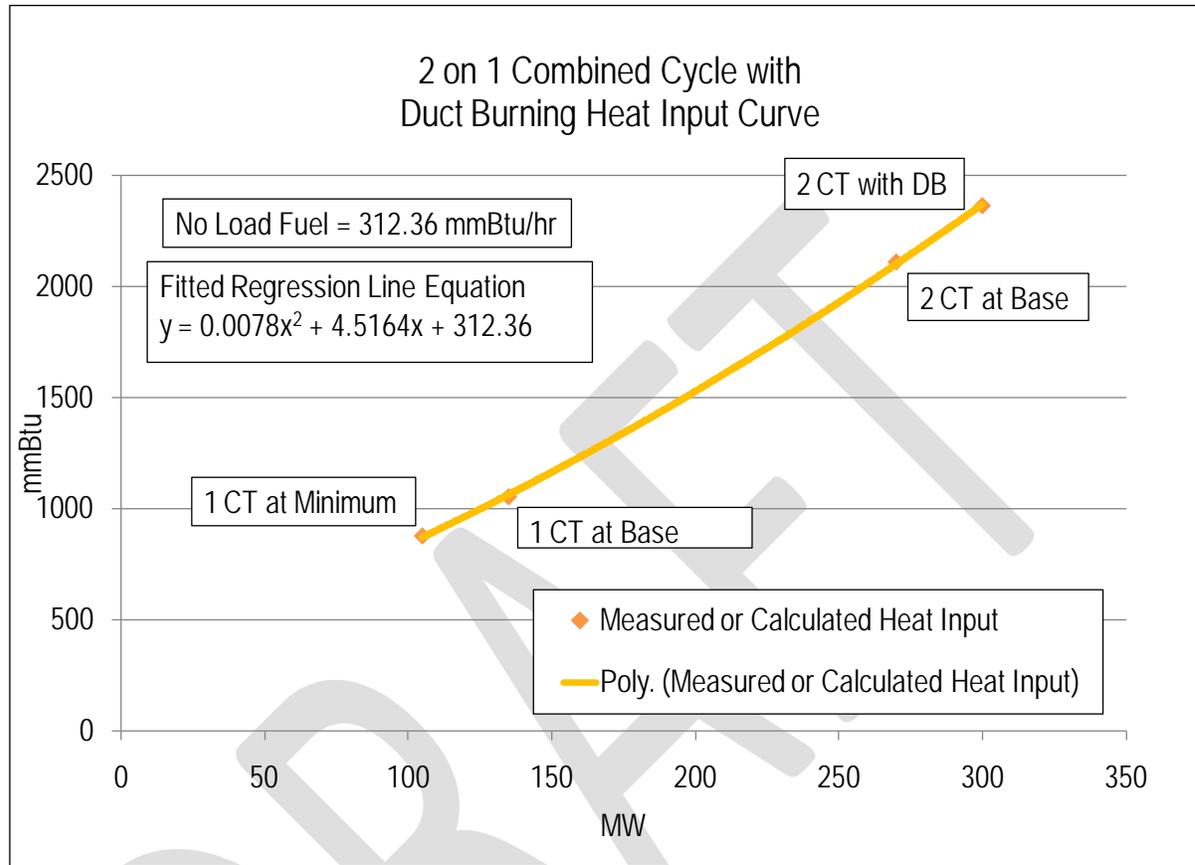
The no-load cost is calculated by subtracting the incremental cost (unit's economic minimum cost-offer value multiplied by MW value) at the unit's economic minimum point from the total cost (from the heat input at economic minimum value) at the unit's economic minimum point.

$$\begin{aligned}
 \text{No - Load Cost (\$/hr)} &= \\
 &= (\text{Economic Minimum Heat Input} * \text{Performance Factor} * \text{TFRC}) + \text{VOM} \\
 &\quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 &= (879.02\text{mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu}) + (\$75.00/\text{ESH}) - (\$32.83/\text{MWh} * 70 \text{ MW}) \\
 &= \$1,363.30/\text{hr}
 \end{aligned}$$

Differences in the calculated No-Load 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 block average method, the user cannot select "Use Offer Slope" when entering cost information into eMKT. When using the derivative method, user must select "Use Offer slope" when entering cost information into eMKT.

### 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 combined cycle with duct burners is shown below:



Each marker 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 Output with natural gas as a fuel:

$$\text{Heat Input (mmBTU/Hr)} = 0.0078 * MW^2 + 4.5164 * MW + 312.36$$

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:

$$\text{No Load Cost}(\$/ \text{ Hour}) =$$

$$(\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC})$$

When assuming the Performance Factor = 1.02 and Total Fuel Related Cost (TFRC) = \$4.00 mmBtu

$$\begin{aligned} \text{No Load Cost}(\$/ \text{ Hour}) \\ &= 312.36 \text{ mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} \\ &= \$1,274/\text{hr} \end{aligned}$$

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 outputs. Total Operating Cost is calculated by:

$$\begin{aligned} \text{Total Operating Cost} (\$/\text{hr}) \\ &= \text{Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{Maintenance Factor} * \text{VOM} \end{aligned}$$

The Maintenance Factor is assumed to be equal to 1.0 for Minimum & Base and VOM is assumed to be equal to \$75.00/ESH, then the Total Operating Costs (\$/hr) at 105 MW is:

$$\begin{aligned} \text{Total Operating Cost} (\$/\text{hr})\text{at } 105 \text{ MW} \\ &= 872.58\text{mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} + (1.0 * \$75/\text{ESH}) \\ &= \$3,635/\text{hr} \end{aligned}$$

The total operating costs at various outputs are shown below:

<u>Output (MW)</u>	<u>Heat Input (mmBtu/hr)</u>	<u>Total Operating Cost (\$/hr)</u>
<u>105</u>	<u>872.58</u>	<u>3,635</u>
<u>135</u>	<u>1064.23</u>	<u>4,417</u>
<u>270</u>	<u>2100.41</u>	<u>8,720</u>
<u>300</u>	<u>2369.28</u>	<u>9,817</u>

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

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

The Incremental Block Average Cost for the first interval at 105 MW is calculated where MW2 = 105 MW, MW1 = 0 MW, Total Operating Cost at 105 MW = \$3,635/hr and the Total Operating Cost at No Load = \$1,274/hr:

$$\begin{aligned} \text{Incremental Block Average Cost (\$/MWh) at 105 MW} \\ &= (\$3,635/\text{hr} - \$1,274/\text{hr}) / (105 - 0) \\ &= \$22.48/\text{MWh} \end{aligned}$$

The incremental block average costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\\$/MWh)</u>
<u>105</u>	<u>22.48</u>
<u>135</u>	<u>26.06</u>
<u>270</u>	<u>31.87</u>
<u>300</u>	<u>32.72</u>

Since the Incremental Block Average Costs are monotonically increasing, no adjustment to the No-Load Cost is required.

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

$$\text{Incremental Cost (\$/MWh)} = ((2 * 0.0078 * \text{MW} + 4.5164) * \text{Performance Factor} * \text{TFRC}) + \Delta \text{VOM} / \Delta \text{MW}$$

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. The Incremental Cost (\\$/MWh) at 105 MW is calculated:

$$\begin{aligned}
 & \text{Incremental Cost (\$/MWh)} \\
 & = ((2 * 0.0078 * 105 \text{ MW} + 4.5164) * 1.02 * \$4.00/\text{mmBtu}) + \$75.00 / \text{ESH} / (105 \text{ MW} \\
 & \quad - 0 \text{ MW}) \\
 & = \$25.82/\text{MWh}
 \end{aligned}$$

The incremental costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\\$/MWh)</u>
<u>105</u>	<u>25.82</u>
<u>135</u>	<u>27.02</u>
<u>270</u>	<u>36.17</u>
<u>300</u>	<u>37.52</u>

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.

$$\begin{aligned}
 & \text{No - Load Cost (\$/hr)} = \\
 & = (\text{Economic Minimum Heat Input} * \text{Performance Factor} * \text{TFRC}) + \text{VOM} \\
 & \quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 & = (872.58\text{mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu}) + (\$75.00/\text{ESH}) - (\$25.82/\text{MWh} * 105 \text{ MW}) \\
 & = \$924.03/\text{hr}
 \end{aligned}$$

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 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 block average method, the user cannot select "Use Offer Slope" when entering cost information into eMKT. When using the derivative method, user must select "Use Offer Slope" when entering cost information into eMKT.

No load fuel consumed shall be the theoretical value of fuel consumed at zero net output from test data or through regression analysis of the input output curve. The minimum number of points to develop a heat input curve shall be 2 points for a dispatch able unit with a variable output and 1 point for a unit with a fixed output.

## B.2 No-Load Cost 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))

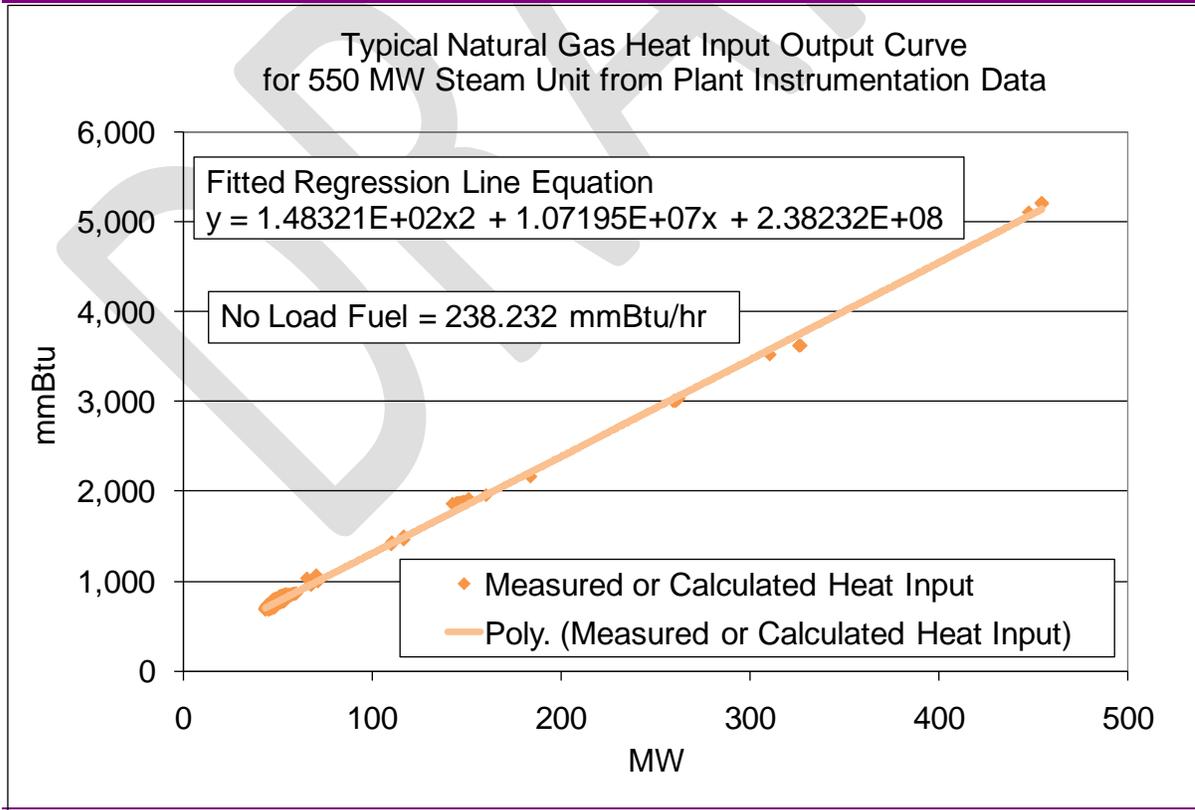
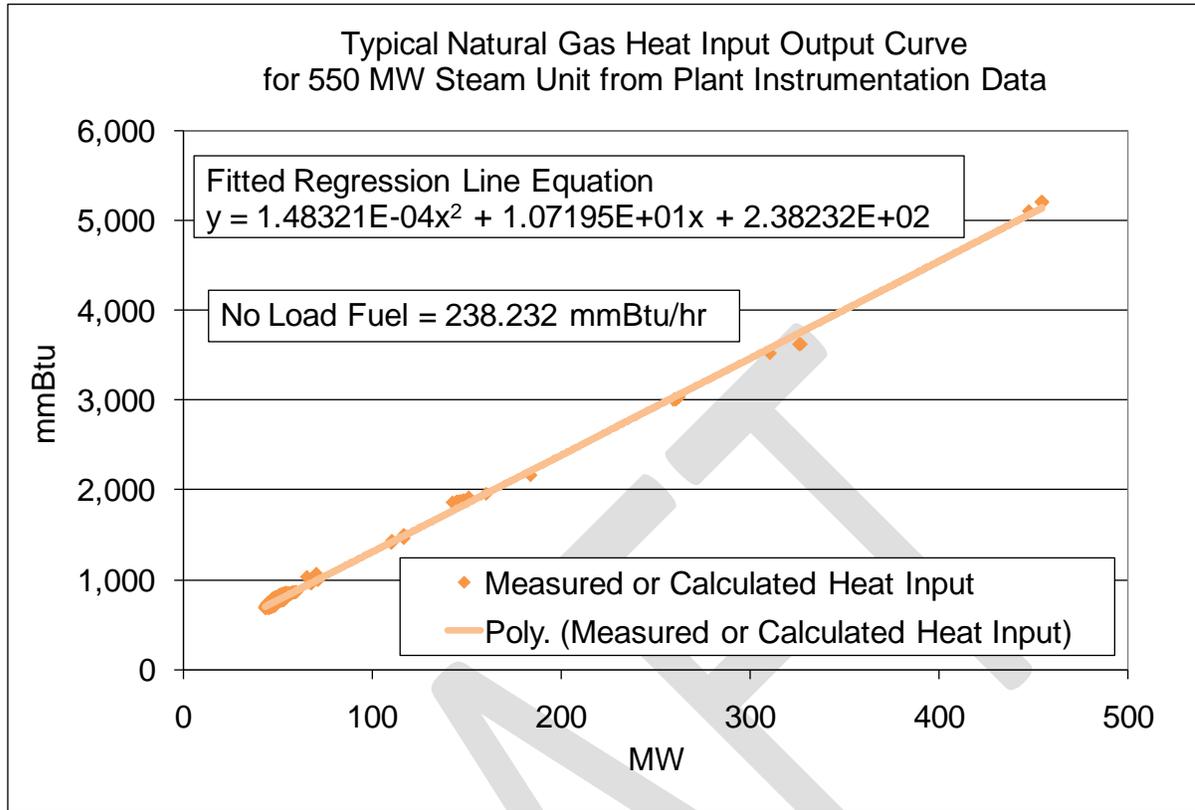
$$\text{No-Load Cost} (\$/\text{Hour}) = (\text{No-Load Fuel} * \text{Performance Factor} * \text{TFRC})$$

### B.35 No-Load Cost Adjustments

The calculated no-load cost should 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 the calculation follows. Heat input values are as a function of output was where collected for a typical fossil fired steam unit and a regression analysis was performed to obtain the no-load.

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Each marker 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 Output with oil as a fuel:

$$\begin{aligned} \text{Heat Input (mmBTU/Hr)} &= \\ &0.000148321 * MW^2 + 10.7195 * MW + 238.232 \end{aligned}$$

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:

$$\begin{aligned} \text{No Load Cost(\$ / Hour)} &= \\ &(\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC}) \end{aligned}$$

When assuming the Performance Factor = 1.02 and Total Fuel Related Cost (TFRC) = \$4.00 mmBtu

$$\begin{aligned} \text{No Load Cost(\$ / Hour)} \\ &= 238.232 \text{ mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} \\ &= \$972/\text{hr} \end{aligned}$$

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 outputs. Total Operating Cost is calculated by:

$$\begin{aligned} \text{Total Operating Cost (\$/hr)} \\ &= \text{Heat Input} * \text{Performance Factor} * (\text{TFRC} + \text{VOM}) \end{aligned}$$

The VOM is assumed to be equal to \$0.15/mmBtu, then the Total Operating Cost (\$/hr) at 50 MW is:

$$\begin{aligned} \text{Total Operating Cost (\$/hr) at 50 MW} \\ &= 774.58 \text{ mmBtu/hr} * 1.02 * (\$4.00/\text{mmBtu} + \$0.15/\text{mmBtu}) \end{aligned}$$

$$= \$3,279/\text{hr}$$

The total operating costs at various outputs are shown in the table below:

<u>Output (MW)</u>	<u>Heat Input (mmBtu/hr)</u>	<u>Total Operating Cost (\$/hr)</u>
<u>50</u>	<u>774.58</u>	<u>3,279</u>
<u>160</u>	<u>1957.15</u>	<u>8,285</u>
<u>310</u>	<u>3575.53</u>	<u>15,135</u>
<u>410</u>	<u>4658.16</u>	<u>19,718</u>
<u>525</u>	<u>5906.85</u>	<u>25,004</u>
<u>550</u>	<u>6178.82</u>	<u>26,155</u>

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

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

The Incremental Block Average Cost for the first interval at 50 MW is calculated where MW2 = 50 MW, MW1 = 0 MW, Total Operating Cost at 50 MW = \$3,279/hr and the Total Operating Cost at No Load = \$972/hr:

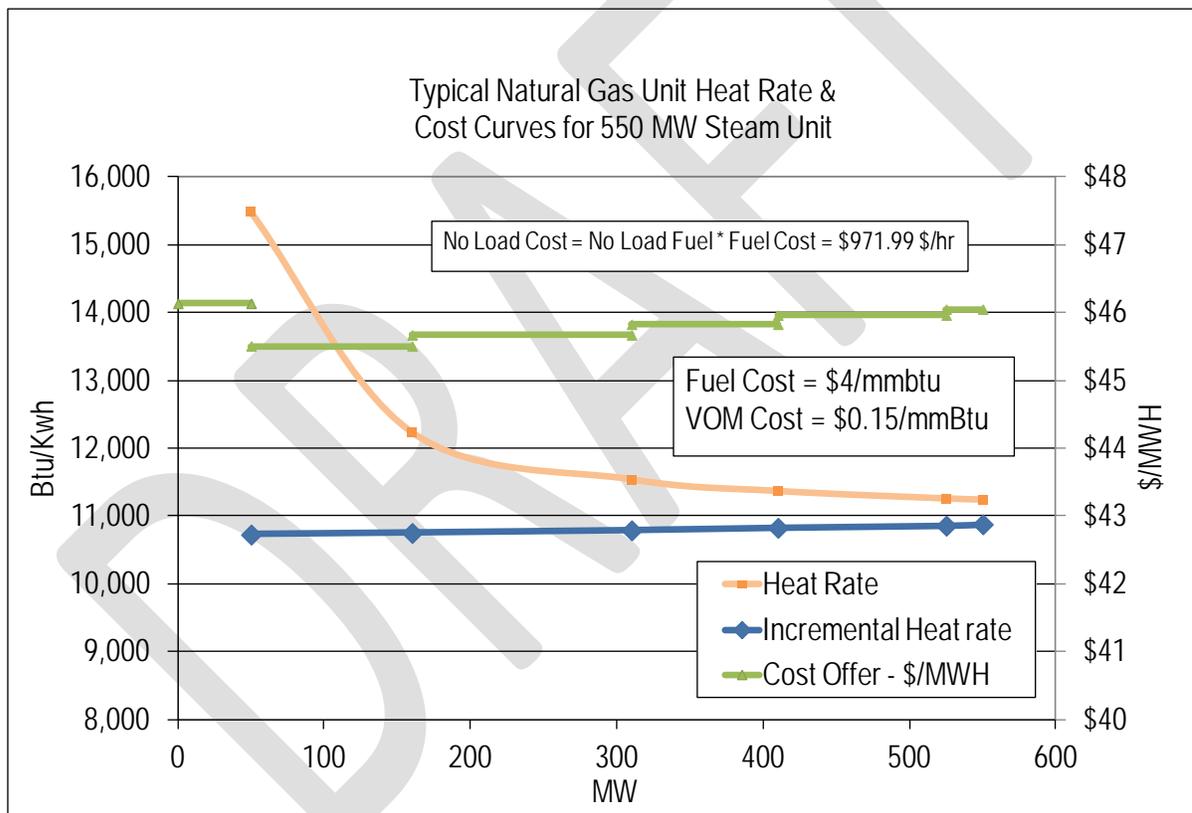
$$\begin{aligned} \text{Incremental Block Average Cost (\$/MWh) at 50 MW} \\ &= (\$3,279/\text{hr} - \$972/\text{hr}) / (50 - 0) \\ &= \$46.14/\text{MWh} \end{aligned}$$

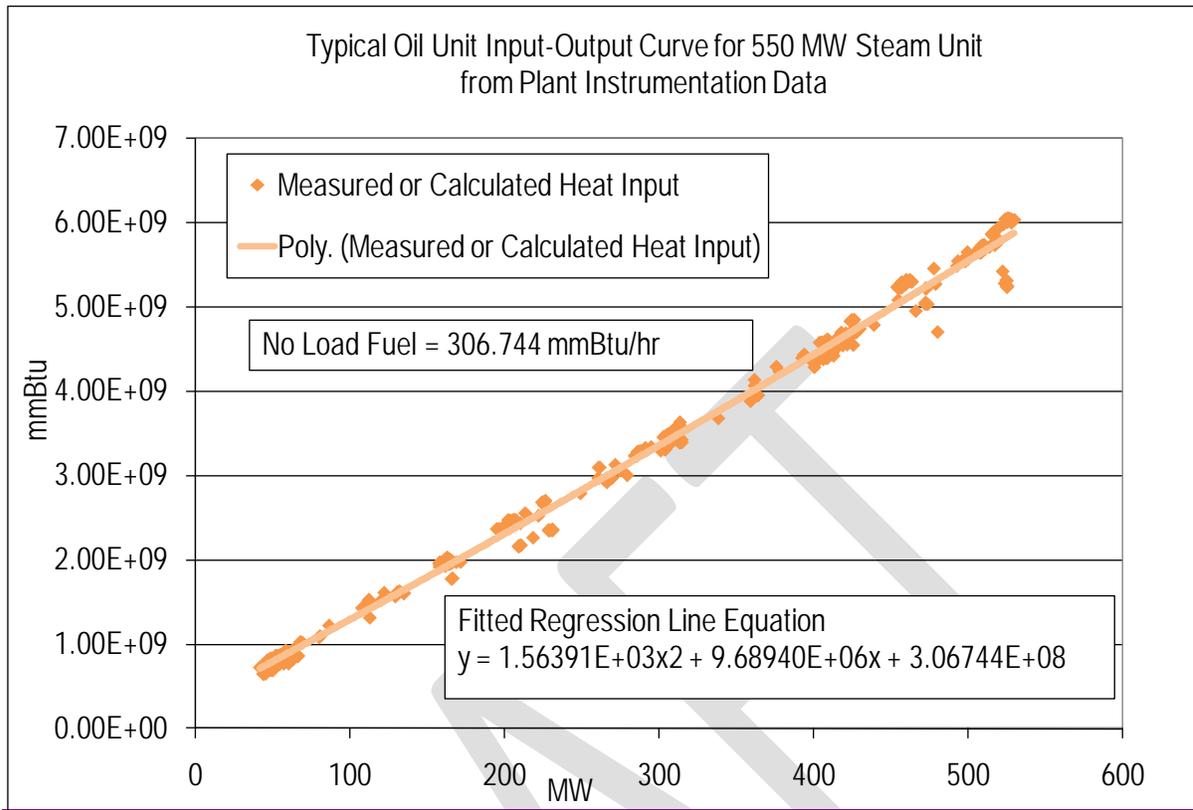
The incremental block average costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\$/MWh)</u>
<u>50</u>	<u>46.14</u>
<u>160</u>	<u>45.51</u>

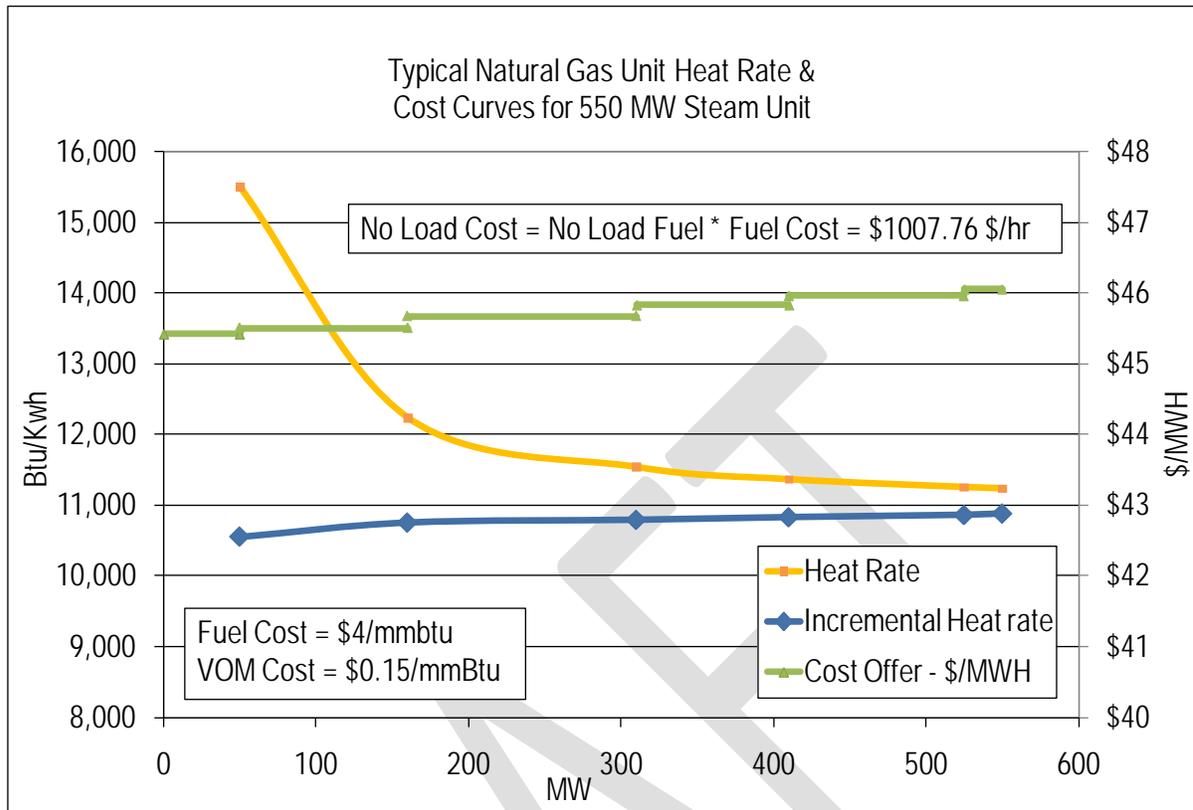
<u>310</u>	<u>45.67</u>
<u>410</u>	<u>45.83</u>
<u>525</u>	<u>45.96</u>
<u>550</u>	<u>46.05</u>

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 or equal to below the second increment, producing a monotonically increasing curve in the graph below:-



To avoid making adjustments to the No-Load, first calculate the unit's Incremental Cost (\$/MWh) at various outputs using the derivative of the Heat Input Curve:

$$\text{Incremental Cost (\$/MWh)} = (2 * 0.000148321 * \text{MW} + 10.7195) * \text{Performance Factor} * (\text{TFRC} + \text{VOM})$$

The Incremental Cost (\$/MWh) at 50 MW is calculated:

$$\begin{aligned} \text{Incremental Cost (\$/MWh)} \\ &= (2 * 0.000148321 * 50 \text{ MW} + 10.7195) * 1.02 * (\$4.00/\text{mmBtu} + \$0.15/\text{mmBtu}) \\ &= \$45.43/\text{MWh} \end{aligned}$$

The incremental costs for other intervals are shown in the table below:

<u>Output (MW)</u>	<u>Incremental Cost (\$/MWh)</u>
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<u>50</u>	<u>45.43</u>
<u>160</u>	<u>45.58</u>
<u>310</u>	<u>45.76</u>
<u>410</u>	<u>45.89</u>
<u>525</u>	<u>46.03</u>
<u>550</u>	<u>46.06</u>

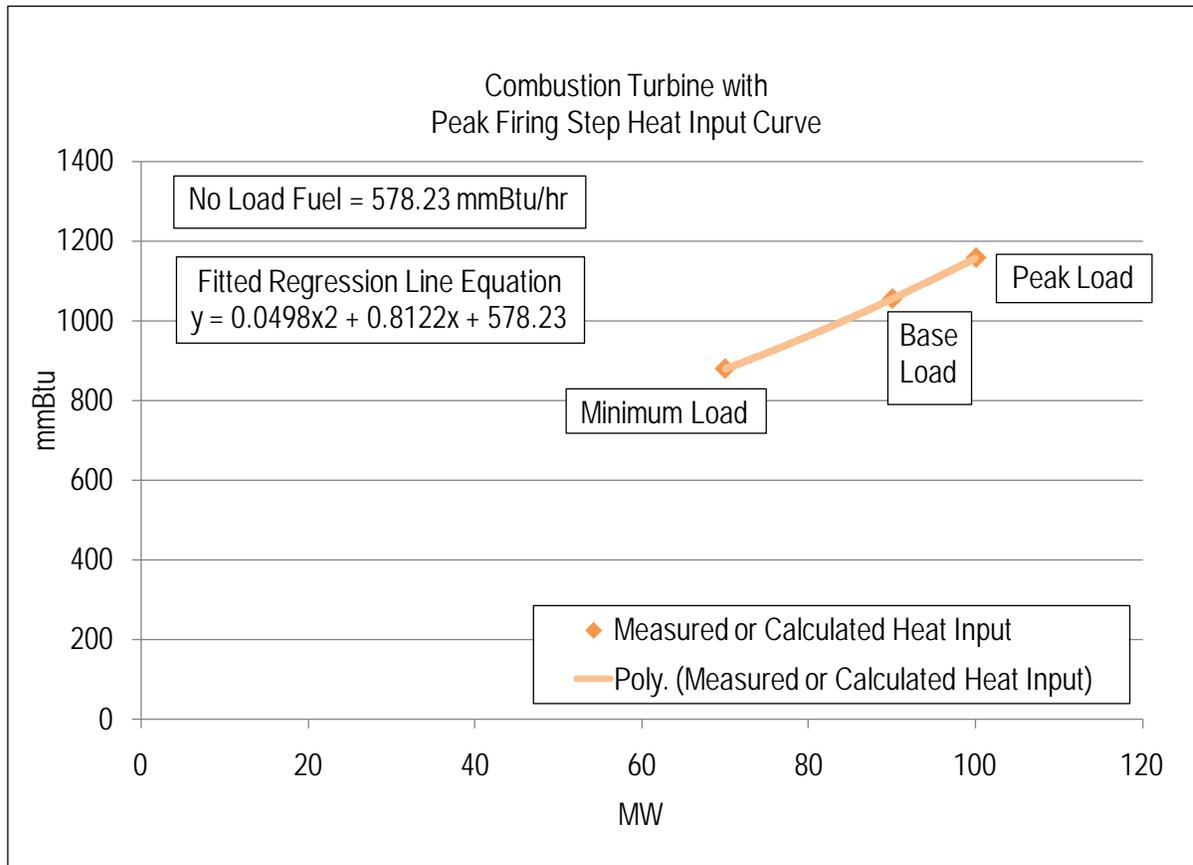
The no-load cost is calculated by subtracting the incremental cost (unit's economic minimum cost-offer value multiplied by MW value) at the unit's economic minimum point from the total cost (from the heat input at economic minimum value) at the unit's economic minimum point.

$$\begin{aligned}
 \text{No - Load Cost (\$/hr)} &= \\
 &= (\text{Economic Minimum Heat Input} * \text{Performance Factor} * (\text{TRFC} + \text{VOM})) \\
 &\quad - (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW}) \\
 &= (774.58\text{mmBtu/hr} * 1.02 * (\$4.00/\text{mmBtu} + \$0.15/\text{mmBtu})) - (\$45.43/\text{MWh} * 50 \text{ MW}) \\
 &= \$1007.3/\text{hr}
 \end{aligned}$$

Differences in the calculated No-Load 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 block average method, the user cannot select "Use Offer Slope" when entering cost information into eMKT. When using the derivative method, user must select "Use Offer Slope" when entering cost information into eMKT.

### 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 marker 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 Output with natural gas as a fuel:

$$\begin{aligned} \text{Heat Input (mmBTU/Hr)} &= \\ &= 0.0498 * MW^2 + 0.8122 * MW + 578.23 \end{aligned}$$

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.

$$\begin{aligned} \text{No Load Cost(\$ / Hour)} &= \\ &= \$0/\text{hr} \end{aligned}$$

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).

$$\begin{aligned}\text{Heat Input (mmBTU/Hr)} &= \\ &0.0498 * MW^2 + 0.8122 * MW + 578.23 \\ &0.0498 * (100)^2 + 0.8122 * (100) + 578.23 \\ &= 1157.28 \text{ mmBtu/hr}\end{aligned}$$

Total Operating Cost at 100 MW where the Maintenance Factor = 1.0 for Minimum & Base, 4.0 for Peak, and VOM = \$75.00/ESH is calculated by:

$$\begin{aligned}\text{Total Operating Cost (\$/hr)} &= \text{Heat Input} * \text{Performance Factor} * \text{TFRC} + \text{Maintenance Factor} * \text{VOM} \\ &= 1157.28 \text{ mmBtu/hr} * 1.02 * \$4.00/\text{mmBtu} + 4.0 * \$75/\text{hr} \\ &= \$5,022/\text{hr}\end{aligned}$$

The unit's Incremental Cost (\$/MWh) at maximum output with a zero No-Load Cost is calculated by:

$$\begin{aligned}\text{Incremental Cost (\$/MWh)} &= \\ &\text{Total Operating Cost Maximum Output}/(\text{Maximum Output}) \\ &(\$5,022)/(100\text{MW}) \\ &= \$50.22 /\text{MWh}\end{aligned}$$