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.

N**o-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, tThe 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, neededrequired 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, tThe no-load heat input curve may be determined by collecting heat input values as a function of output and performing a regression analysisextrapolating 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 dataheat 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.[LW1]

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))

$$No\ Load\ Cost(\$ / Hour) =$$

$$(No\ Load\ Fuel * Performance\ Factor * TFRC)$$

~~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 ~~oO~~ffer ~~Cc~~urve is monotonically increasing. The No-Load cost adjustment is limited to a maximum difference of $1/MW~~h~~ between the unit's first and second incremental cost offers.

As an alternative to adjusting the no-load cost, ~~The no-load cost is~~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.

$$No\ Load\ Cost(\$ / Hour) =$$

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

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

~~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:

$$No\ Load\ Cost(\$ / Hour) =$$

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

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

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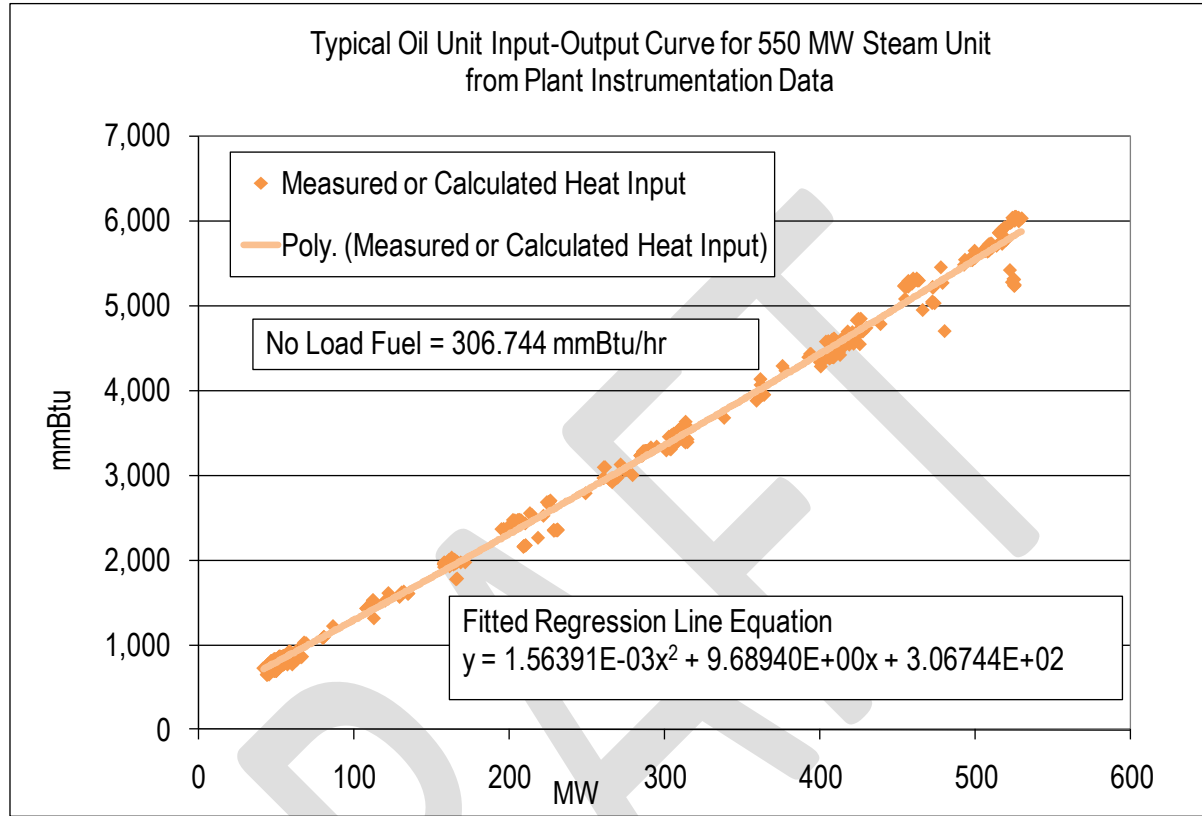
Using the initial design heat input curve for an immature unit and performing a regression analysis

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

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:

Typical Oil Unit Input-Output Curve for 550 MW Steam Unit from Plant Instrumentation Data

- Measured or Calculated Heat Input
- Poly. (Measured or Calculated Heat Input)

No Load Fuel = 306.744 mmBtu/hr

Fitted Regression Line Equation
$y = 1.56391\text{E-}03x^2 + 9.68940\text{E+}00x + 3.06744\text{E+}02$

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 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

$$No - Load\ Fuel = 306.744\ \text{mmBtu/hr}$$

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

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = $14.00 mmBtu

$$No\ Load\ Cost(\$ / Hour) =$$

$$(\ No\ Load\ Fuel * Performance\ Factor * TFRC)$$

$$= 306.744\ mmBtu/hr\ * 1.02 * \$14.00/mmBtu$$

$$= \$4{,}380/hr$$

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

$$Total\ Operating\ Cost\ (\$/hr)$$

$$= Heat\ Input * Performance\ Factor * (TFRC + VOM)$$

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:

$$Incremental\ Cost\ (\$/MWh) =$$

$$Total\ Operating\ Cost\ MW2 - Total\ Operating\ Cost\ MW1/(MW2 - \ MW1)$$

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 outputs can also be determined by using the derivative of the Heat Input Curve:

$$\text{Incremental Cost (\$/MWh)} =$$

$$(2 * 0.00156391 * \text{MW} + 9.6894) * \text{Performance Factor } * (\text{TFRC} + \text{VOM})$$

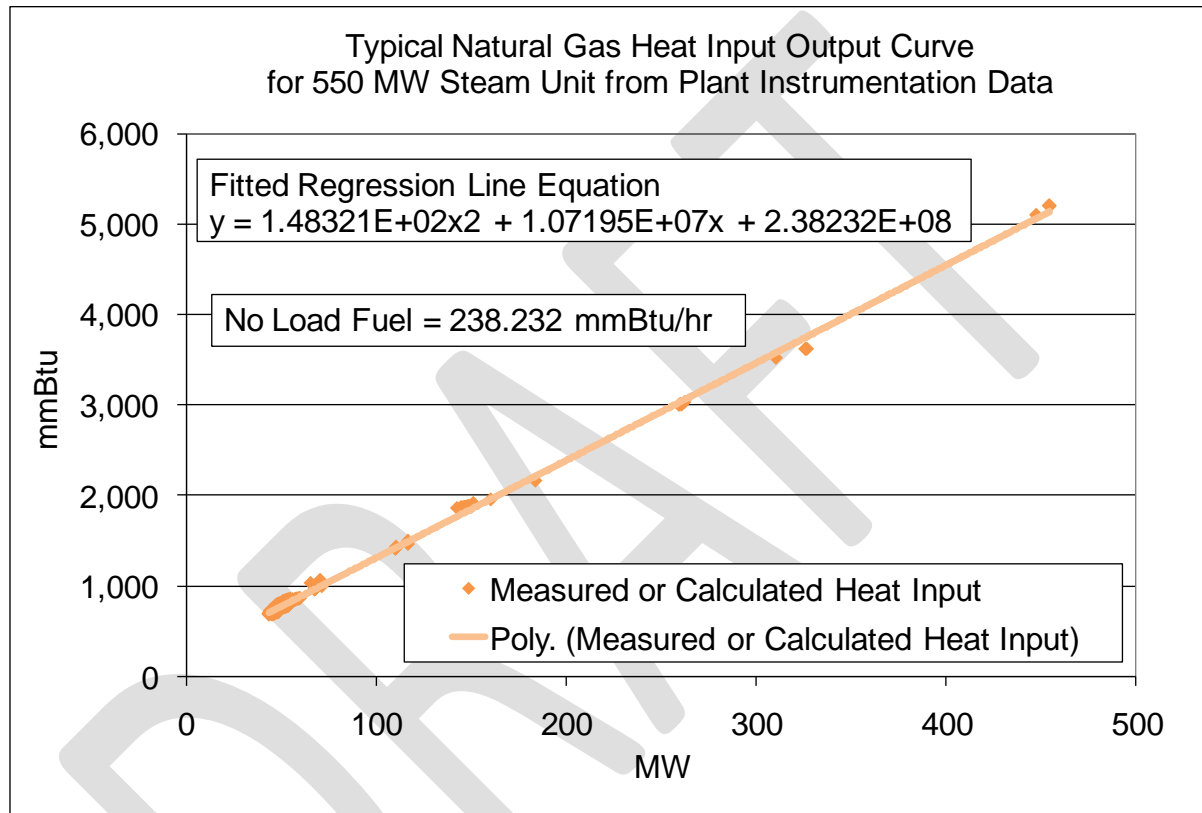| Output (MW)	Incremental Cost ($/MWh)
50	142.10
160	147.07
310	153.84
410	158.36
525	163.55
550	164.68

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.

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

$$= \big(\text{Economic Minimum Heat Input} * \text{Performance Factor} * (\text{TRFC} + \text{VOM})\big)$$
$$- (\text{Economic Minimum Incremental Cost} * \text{Economic Minimum MW})$$

$$= (795.12 \text{mmBtu/hr} * 1.02 * (\$14.00/\text{mmBtu} + \$0.15/\text{mmBtu})) - (\$142.10/\text{MWh} * 50 \text{ MW})$$

$$= \$4,370.97/\text{hr}$$

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 derivative method, user must select "Use Sloped Offer" when entering cost information into eMKT.

Typical Natural Gas Heat Input Output Curve
for 550 MW Steam Unit from Plant Instrumentation Data

Fitted Regression Line Equation
$y = 1.48321E+02x2 + 1.07195E+07x + 2.38232E+08$

No Load Fuel = 238.232 mmBtu/hr

Legend:
- ◆ Measured or Calculated Heat Input
- — Poly. (Measured or Calculated Heat Input)

Y-axis: mmBtu
X-axis: MW

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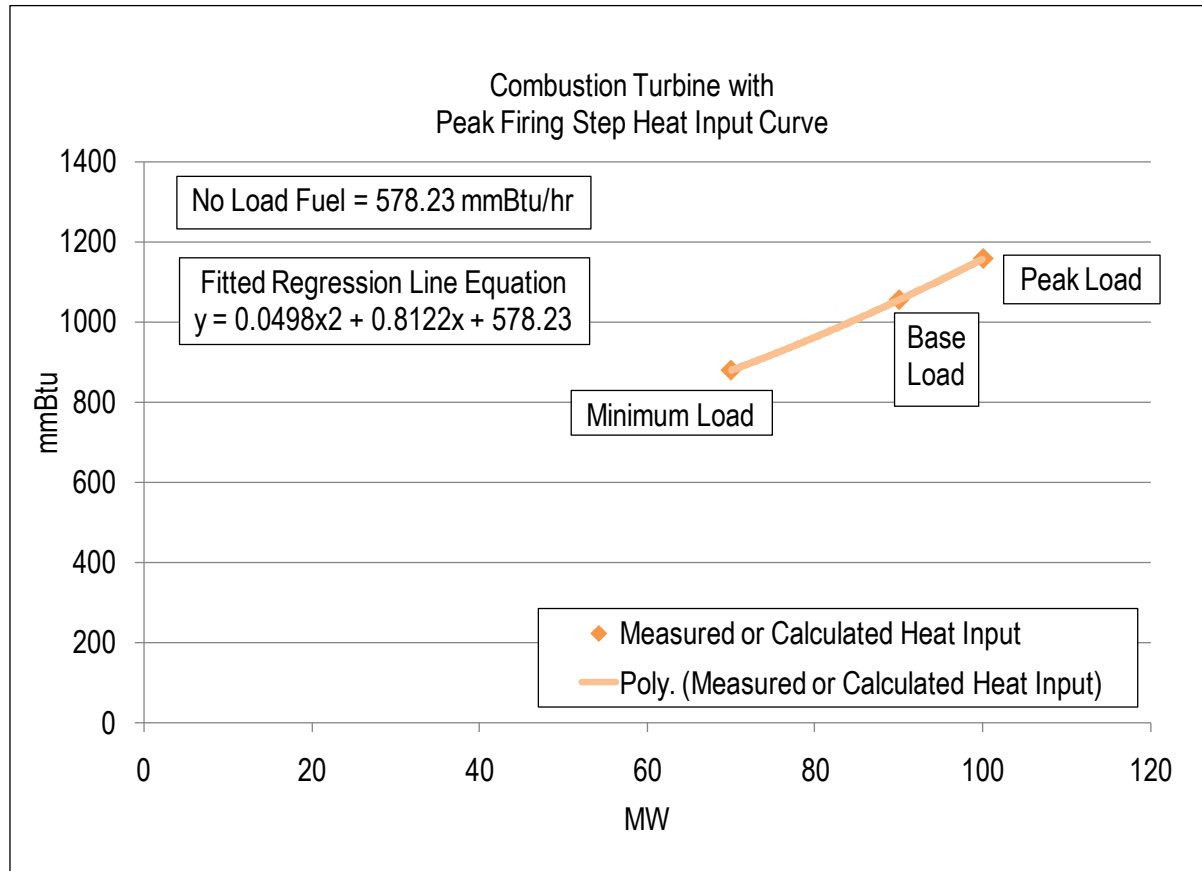
Each diamond in the graph above is a design heat input data point obtained from the original equipment manufacturer or calculated by heat balance. A regression analysis was performed on the design data to obtain the unit's Heat Input curve as a function of Output with natural gas as a fuel:

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

Then the No-Load Fuel at zero output is

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

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

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = $4.00 mmBtu

$$\text{No Load Cost(\$ / Hour)} =$$
$$(\text{ No Load Fuel} * \text{Performance Factor} * \text{TFRC})$$
$$= 578.23 \text{mmBtu/hr} * 1.02 * \$4.00\text{/mmBtu}$$
$$= \$2,359\text{/hr}$$

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:

Maintenance Factor = 1.0 for Minimum & Base   (=4.0 for Peak)

VOM = $75.00/ESH

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

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 outputs can be determined arithmetically by the following equation:

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

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 outputs can also be determined by using the derivative of the Heat Input Curve:

$$Incremental\ Cost\ (\$/MWh) =$$

$$\left((2 * 0.0498 * MW + 0.8122) * Performance\ Factor * \ TFRC\right) + \ \Delta VOM/\Delta MW$$

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.

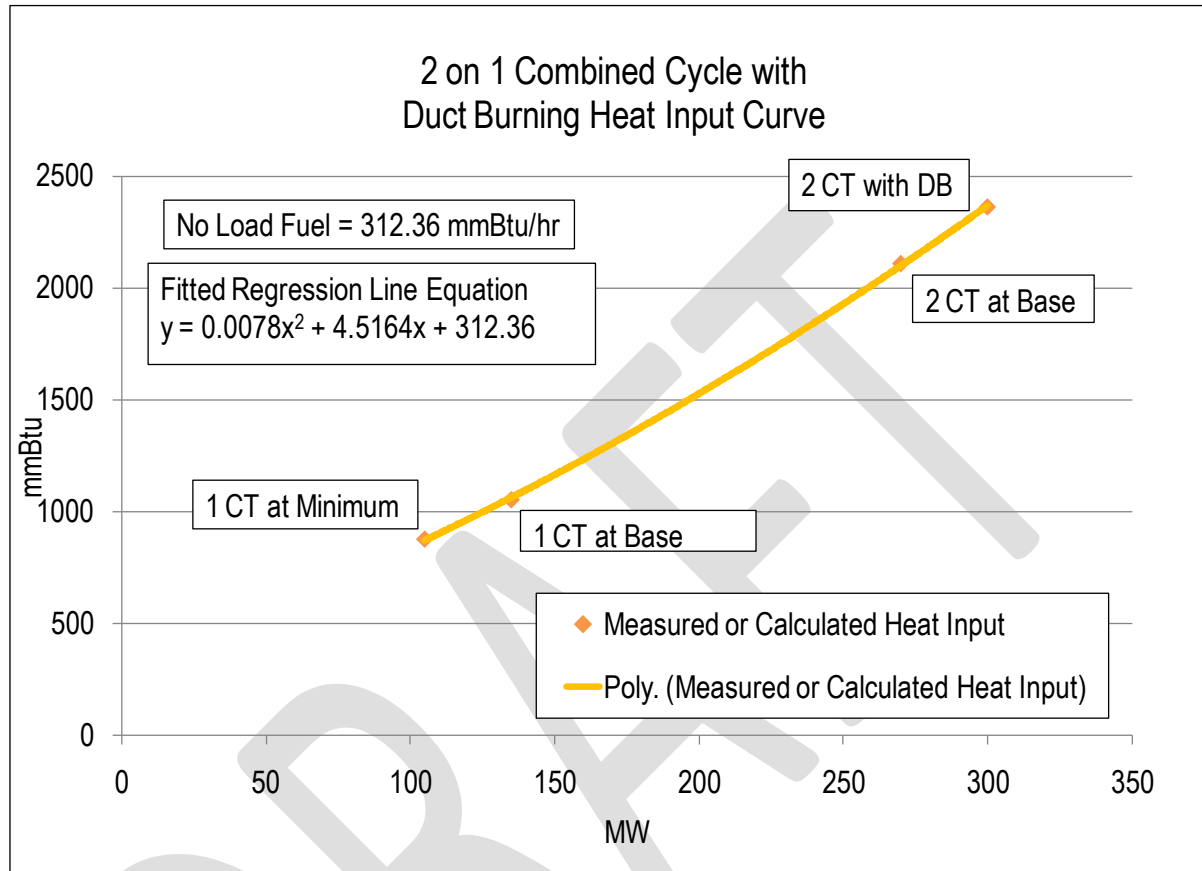| Output (MW)	Incremental Cost ($/MWh)
70	32.83
90	39.89
100	66.45

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.

$$No - Load\ Cost\ (\$/hr) =$$

$$= (Economic\ Minimum\ Heat\ Input * Performance\ Factor * TFRC) + VOM$$
$$- (Economic\ Minimum\ Incremental\ Cost * Economic\ Minimum\ MW)$$

$$= (879.02mmBtu/hr * 1.02 * \$4.00/mmBtu) + (\$75.00/ESH) - (\$32.83/MWh * 70\ MW)$$

$$= \$1,363.30/hr$$

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 derivative method, user must select "Use Sloped Offer" 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:

2 on 1 Combined Cycle with Duct Burning Heat Input Curve

No Load Fuel = 312.36 mmBtu/hr

Fitted Regression Line Equation
y = 0.0078x² + 4.5164x + 312.36

Labels on chart: 2 CT with DB, 2 CT at Base, 1 CT at Minimum, 1 CT at Base

Legend: ◆ Measured or Calculated Heat Input — Poly. (Measured or Calculated Heat Input)

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 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

$$No - Load\ Fuel = 312.36\ \text{mmBtu/hr}$$

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

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = $4.00 mmBtu

$$No\ Load\ Cost(\$ / Hour) =$$
$$(No\ Load\ Fuel * Performance\ Factor * TFRC)$$
$$= 312.36\ mmBtu/hr\ * 1.02 * \$4.00/mmBtu$$
$$= \$1,274/hr$$

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:

Maintenance Factor = 1.0

VOM = $75.00/ESH

$$Total\ Operating\ Cost\ (\$/hr)$$
$$= Heat\ Input * Performance\ Factor * TFRC + Maintenance\ Factor *\ VOM$$

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 outputs can be determined arithmetically by the following equation:

$$Incremental\ Cost\ (\$/MWh) =$$
$$Total\ Operating\ Cost\ MW2 - Total\ Operating\ Cost\ MW1/(MW2 -\ MW1)$$

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 outputs can also be determined by using the derivative of the Heat Input Curve:

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

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.

Output (MW)	Incremental Cost ($/MWh)
105	25.82
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.

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

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 derivative method, user must select "Use Sloped Offer" 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.
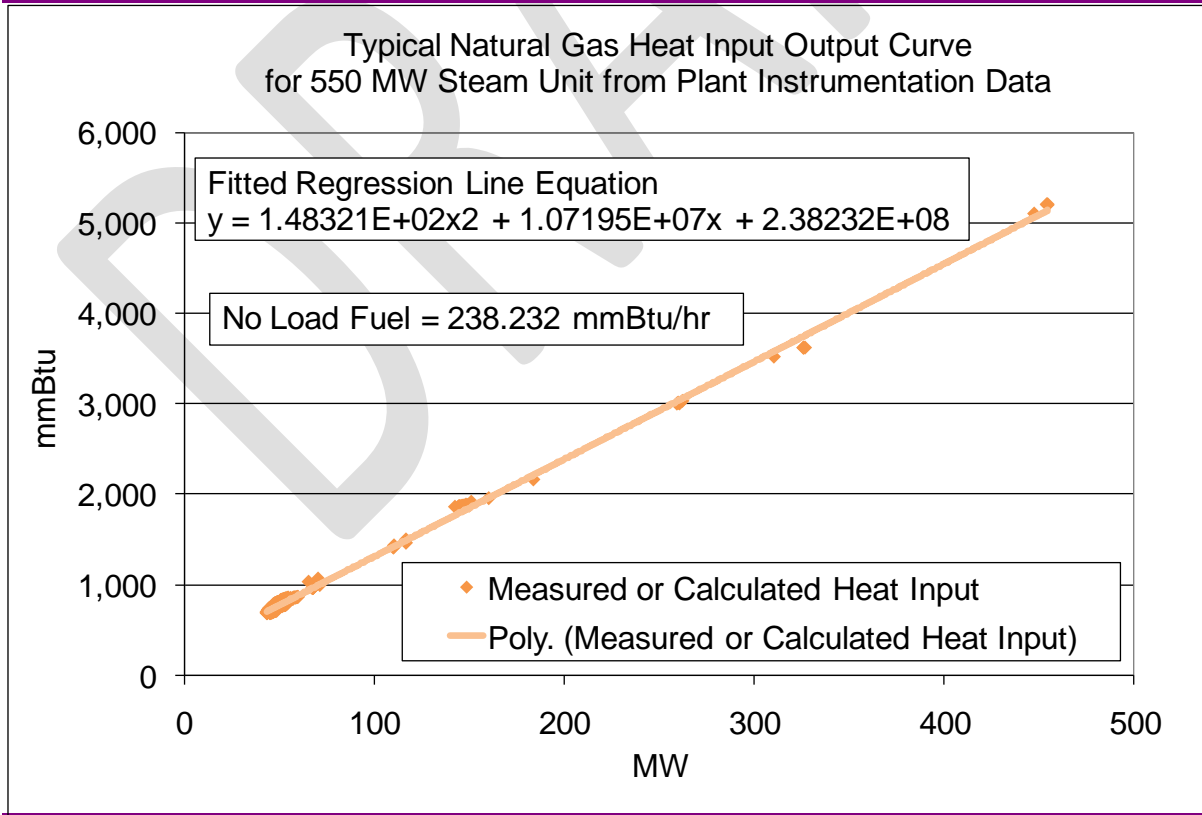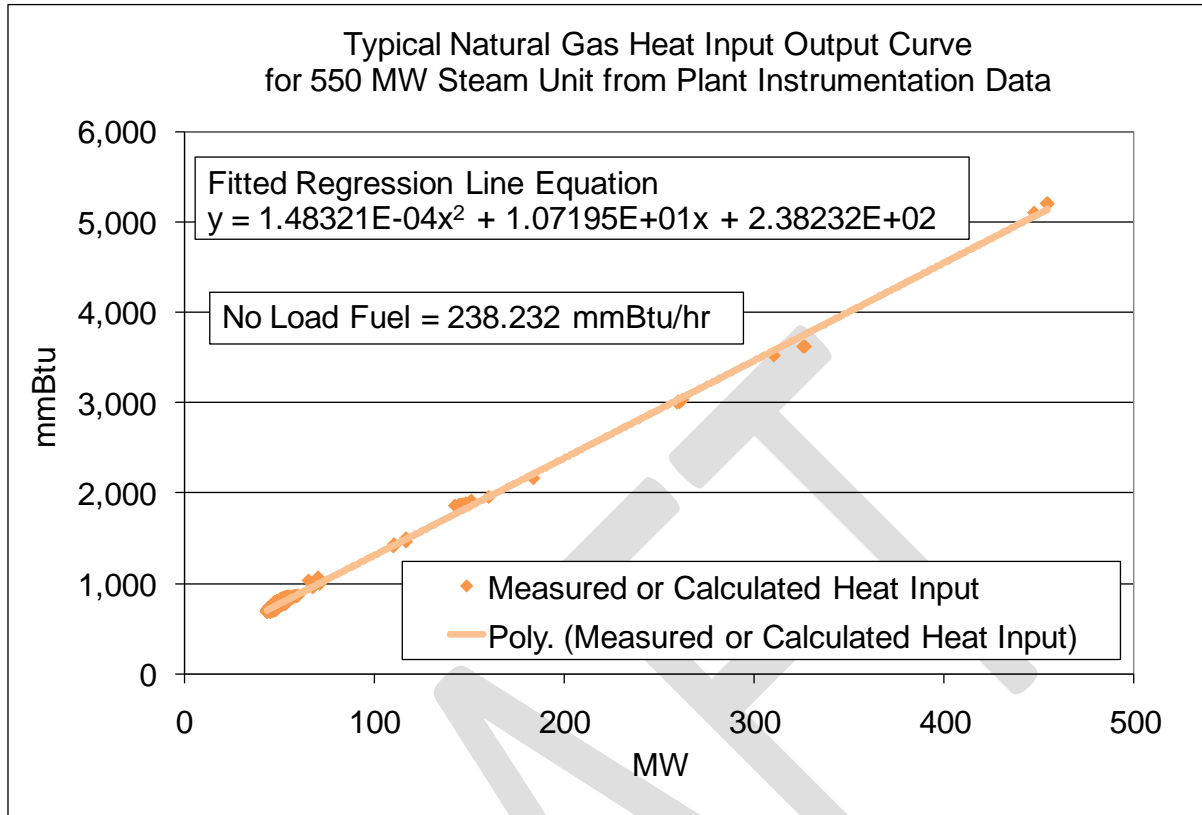
B.2 No-Load Cost Calculation

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))

$$No\ Load\ Cost(\$ / Hour) =$$

$$(No\ Load\ Fuel * Performance\ Factor * TFRC)$$

B.35 No-Load Cost Adjustments

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

Typical Natural Gas Heat Input Output Curve for 550 MW Steam Unit from Plant Instrumentation Data

Fitted Regression Line Equation
$y = 1.48321E\text{-}04x^2 + 1.07195E\text{+}01x + 2.38232E\text{+}02$

No Load Fuel = 238.232 mmBtu/hr

- ◆ Measured or Calculated Heat Input
- —— Poly. (Measured or Calculated Heat Input)

MW

mmBtu

Typical Natural Gas Heat Input Output Curve for 550 MW Steam Unit from Plant Instrumentation Data

Fitted Regression Line Equation
$y = 1.48321E\text{+}02x2 + 1.07195E\text{+}07x + 2.38232E\text{+}08$

No Load Fuel = 238.232 mmBtu/hr

- ◆ Measured or Calculated Heat Input
- —— Poly. (Measured or Calculated Heat Input)

MW

mmBtu

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 Output 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

$$\text{No} - \text{Load Fuel} = 238.232 \text{ mmBtu/hr}$$

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

Performance Factor = 1.02

Total Fuel related Cost (TFRC) = $4.00 mmBtu

$$\text{No Load Cost(\$ / Hour)} =$$
$$(\text{No Load Fuel} * \text{Performance Factor} * \text{TFRC})$$
$$= 238.232 \; mmBtu/hr \; * 1.02 * \$4.00/mmBtu$$
$$= \$972/hr$$

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

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

Output (MW)	Heat Input (mmBtu/hr)	Total Operating Cost ($/hr)
50	774.58	3,279
160	1957.15	8,285

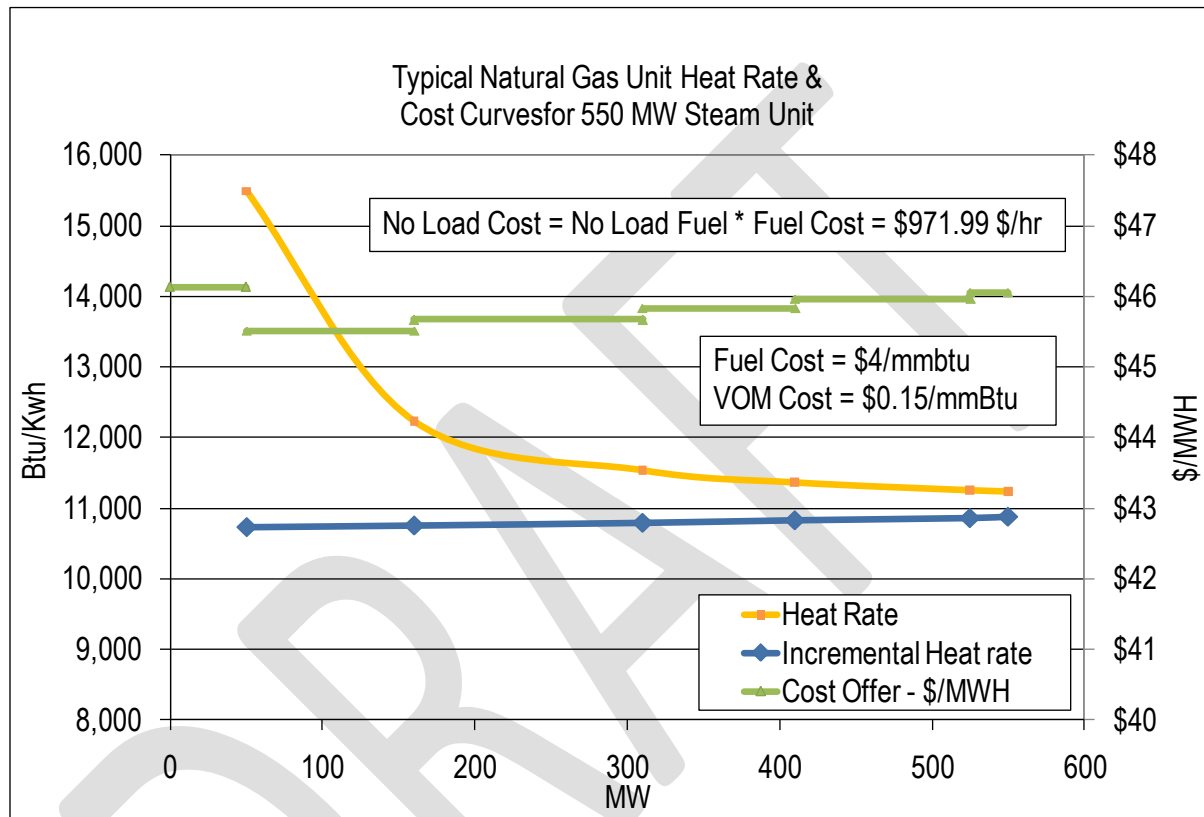|		
310	3575.53	15,135
410	4658.16	19,718
525	5906.85	25,004
550	6178.82	26,155

The unit's Incremental Cost ($/MWh) at various outputs can be determined arithmetically by the following equation:
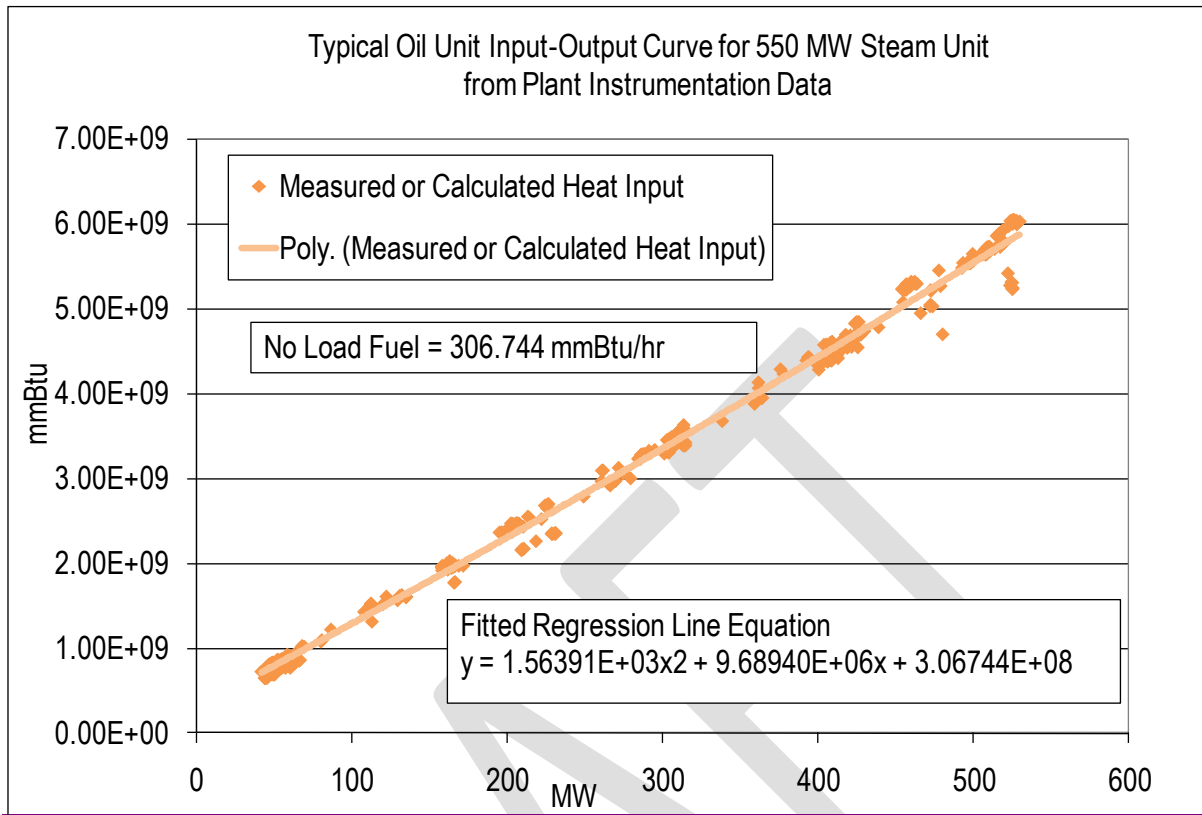
$$\text{Incremental Cost (\$/MWh)} =$$
$$\text{Total Operating Cost MW2} - \text{Total Operating Cost MW1}/(\text{MW2} - \text{MW1})$$

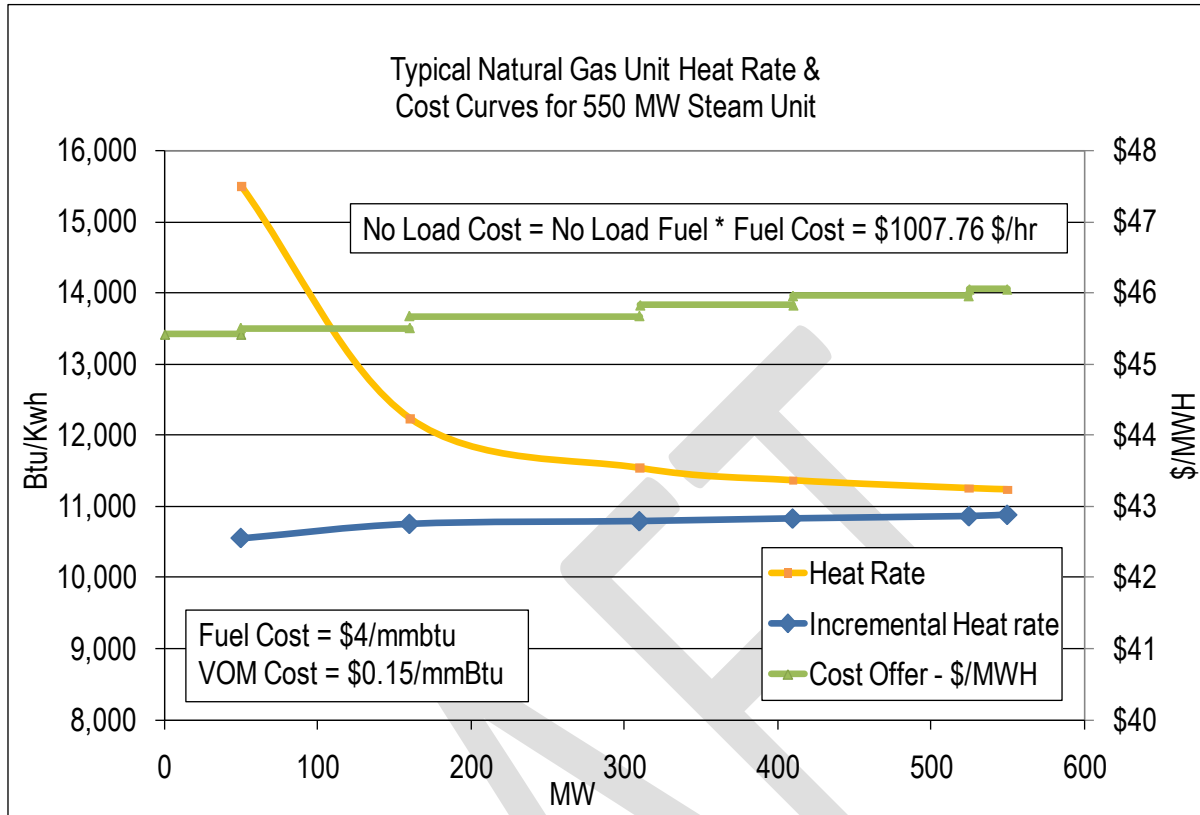| Output (MW)	Incremental Cost ($/MWh)
50	46.14
160	45.51
310	45.67
410	45.83
525	45.96
550	46.05

When calculating the first increment, MW1 is zero and the Total Operating Cost MW1 is the No-Load Cost.

~~Once the No-Load Cost was calculated, the unit's cost curve was then developed.~~ 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:

Typical Natural Gas Unit Heat Rate &
Cost Curvesfor 550 MW Steam Unit

No Load Cost = No Load Fuel * Fuel Cost = $971.99 $/hr

Fuel Cost = $4/mmbtu
VOM Cost = $0.15/mmBtu

Heat Rate
Incremental Heat rate
Cost Offer - $/MWH

Typical Oil Unit Input-Output Curve for 550 MW Steam Unit from Plant Instrumentation Data

No Load Fuel = 306.744 mmBtu/hr

Fitted Regression Line Equation
$y = 1.56391E+03x2 + 9.68940E+06x + 3.06744E+08$

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 tobelow the second increment, producing a monotonically increasing curve in the graph below:.

Typical Natural Gas Unit Heat Rate &
Cost Curves for 550 MW Steam Unit

No Load Cost = No Load Fuel * Fuel Cost = $1007.76 $/hr

Fuel Cost = $4/mmbtu
VOM Cost = $0.15/mmBtu

Legend: Heat Rate, Incremental Heat rate, Cost Offer - $/MWH

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:

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

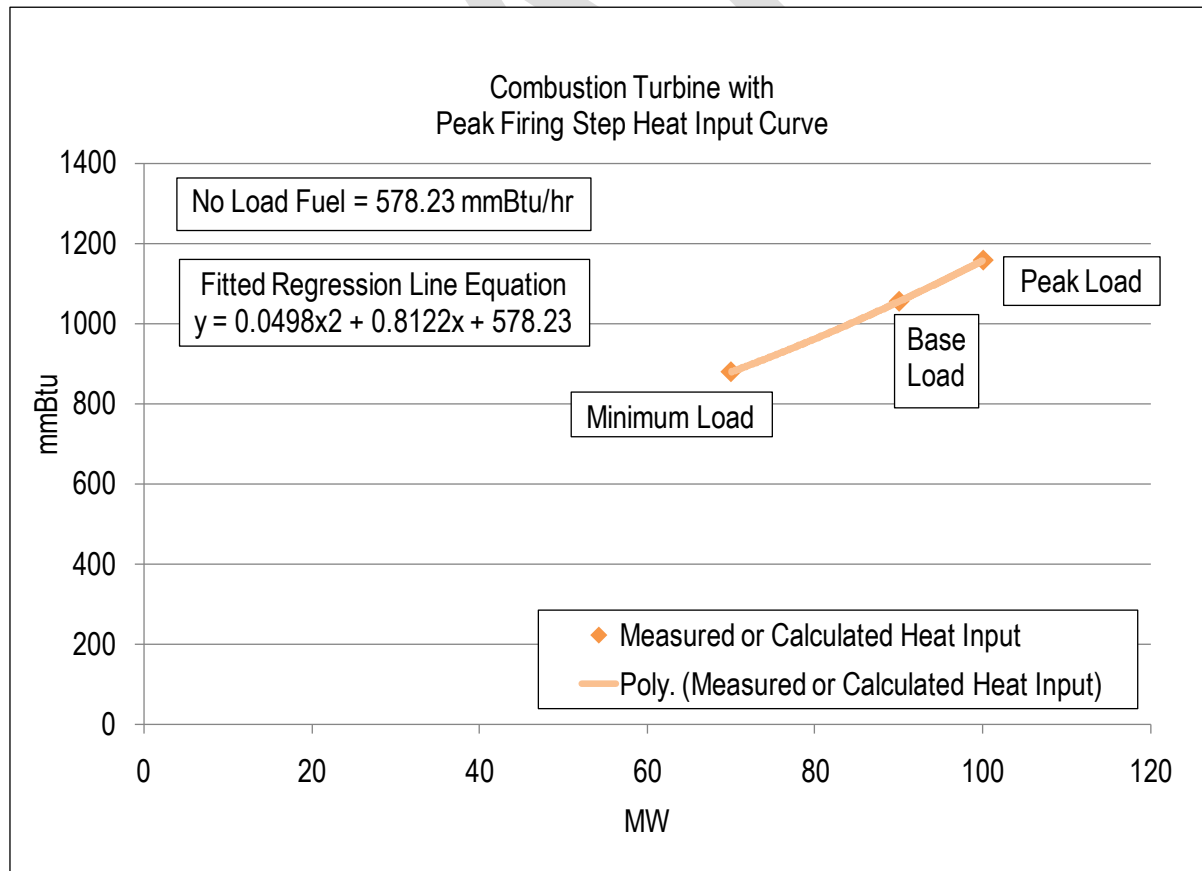| Output (MW)	Incremental Cost ($/MWh)
50	45.43
160	45.58
310	45.76
410	45.89
525	46.03
550	46.06

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.

$$No - Load\ Cost\ (\$/hr) =$$

$$= \big(Economic\ Minimum\ Heat\ Input * Performance\ Factor * (TRFC + VOM)\big)$$
$$- (Economic\ Minimum\ Incremental\ Cost * Economic\ Minimum\ MW)$$

$$= (774.58mmBtu/hr * 1.02 * (\$4.00/mmBtu + \$0.15/mmBtu)) - (\$45.43/MWh * 50\ MW)$$

$$= \$1007.3/hr$$

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 derivative method, user must select "Use Sloped Offer" 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:

Combustion Turbine with
Peak Firing Step Heat Input Curve

No Load Fuel = 578.23 mmBtu/hr

Fitted Regression Line Equation
y = 0.0498x2 + 0.8122x + 578.23

Peak Load

Base Load

Minimum Load

◆ Measured or Calculated Heat Input
— Poly. (Measured or Calculated Heat Input)

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 Output 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.**

$$\text{No Load Cost}(\$ / \text{Hour}) =$$
$$= \$0/\text{hr}$$

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).

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

Total Operating Cost at 100 MW is calculated by:

Maintenance Factor = 1.0 for Minimum & Base   (=4.0 for Peak)

VOM = $75.00/ESH

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

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

$$\text{Incremental Cost (\$/MWh)} =$$

Total Operating Cost Maximum Output/(Maximum Output)

($5,022)/(100MW)

$= \$50.22 \text{ /MWh}$