Energy Offer Calculation Education

CDS

January 14, 2021

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Energy Offer

- **Energy offers are submitted in PJM in up to three parts:**
  - **Incremental Energy Cost Curve**
  - **No Load Cost**
  - **Start Cost**

- **The incremental energy cost curve and no load cost are derived from the efficiency of the unit and fuel costs.**

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Tariff Definitions

- **Incremental Energy Offer** shall mean offer segments comprised of a pairing of price (in dollars per MWh) and megawatt quantities, which must be a non-decreasing function and taken together produce all of the energy segments above a resource's Economic Minimum. No load Costs are not included in the Incremental Energy Offer.

- **No load Cost** shall mean the hourly cost required to create the starting point of a monotonically increasing incremental offer curve for a generating unit.

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Heat Input

- **The incremental energy cost curve is derived using the incremental heat rate curve.**

- **The no load cost is derived using the no load heat.**

- **Both the incremental heat rate curve and no load heat are derived from the heat input curve.**

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Heat Input Curve

- **Heat input curves, also called input/output curves, represent the amount of fuel used to produce energy. Heat input curves are developed based on net energy production. Heat input curves can be developed using historical data, performance test data or Original Equipment Manufacturer (OEM) documentation.**
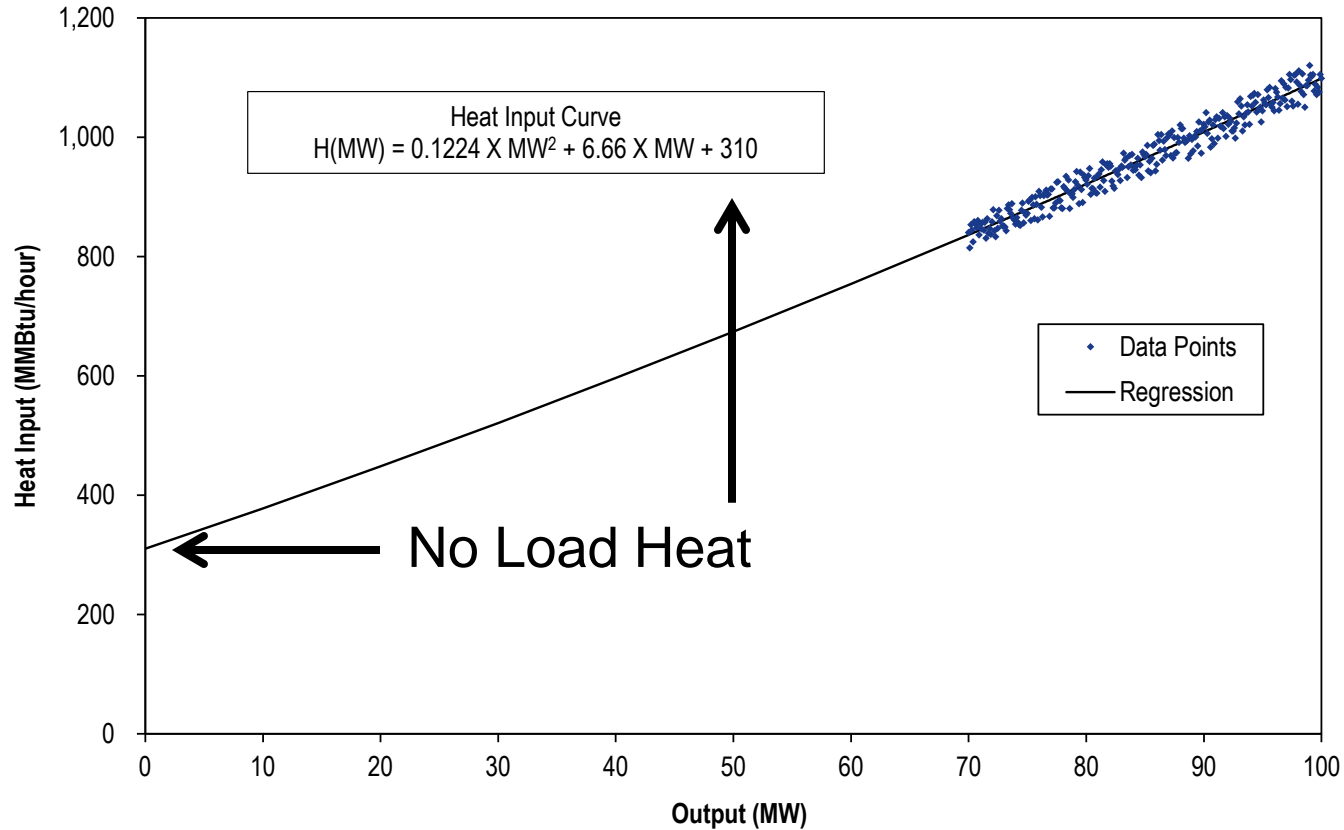
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Heat Input Curve

- Observed fuel heat input and electric output data during normal operation or a performance test provide a direct measure of the heat input curve. A linear regression of the heat input on the energy output can provide an estimated polynomial curve. In the typical case, the heat input curve is a second order polynomial that applies to the entire operating output range of the unit.

- Heat input curves are typically represented using a second order polynomial:

$$H(MW) = X_2 \times MW^2 + X_1 \times MW + X_0$$

Heat Input Curve Example

Heat Input Curve
$H(MW) = 0.1224 \times MW^2 + 6.66 \times MW + 310$

No Load Heat

- Data Points
- Regression

Heat Input (MMBtu/hour)

Output (MW)

No Load Heat

- **The no load heat is the estimated amount of fuel needed to theoretically operate a unit at zero MW. The no load heat is the constant term (X0) of the heat input curve.**

- **The no load cost is equal to the no load heat (MMBtu) times fuel cost ($/MMBtu).**

- **Example:**
  - **No Load Heat = 310 MMBtu/hour**
  - **Fuel Cost = $3/MMBtu**
  - **No Load Cost = $930/hour**

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No Load Cost

- **The no load cost is not a fudged number to create a monotonically nondecreasing incremental cost curve.**

- **The no load cost is not the cost to get the unit to synchronization.**

- **The no load cost is the hourly energy cost required to theoretically operate a unit at zero MW (no load).**

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No Load Cost Equation

- ## No Load Cost

$$NL = H(0) \times (FC + VOM(0) + EC(0)) + VOM_{hour}$$

where:

NL is the no load cost in \$/hour.

$H(0)$ is the no load heat input, the intercept of the heat input curve, in MMBtu.

FC is the fuel cost at MW output of zero, in \$/MMBtu. For units that use a different starting fuel (e.g. coal units), the fuel in the no load cost calculation cannot be the fuel used during startup and synchronization, but must be the fuel used during normal operation.

$VOM(0)$ is the sum of the variable operating cost and maintenance adder at zero MW, in \$/MMBtu.

VOM_{hour} is the sum of the variable operating cost and maintenance adder at zero MW, in \$/hour.

$EC(0)$ is the cost of emission credit allowances at zero MW, in \$/MMBtu.

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Incremental Heat Rate Curve

- **The incremental heat rate curve is the change in heat input required to produce the next MW of output. It varies with the output level. In mathematical terms, it is the first derivative of the heat input function. In PJM, units can have offers based on incremental heat rates using a sloped function or a stepped function.**

Incremental Heat Rate Curve

- **When a sloped function is used, the incremental heat rate function is:**
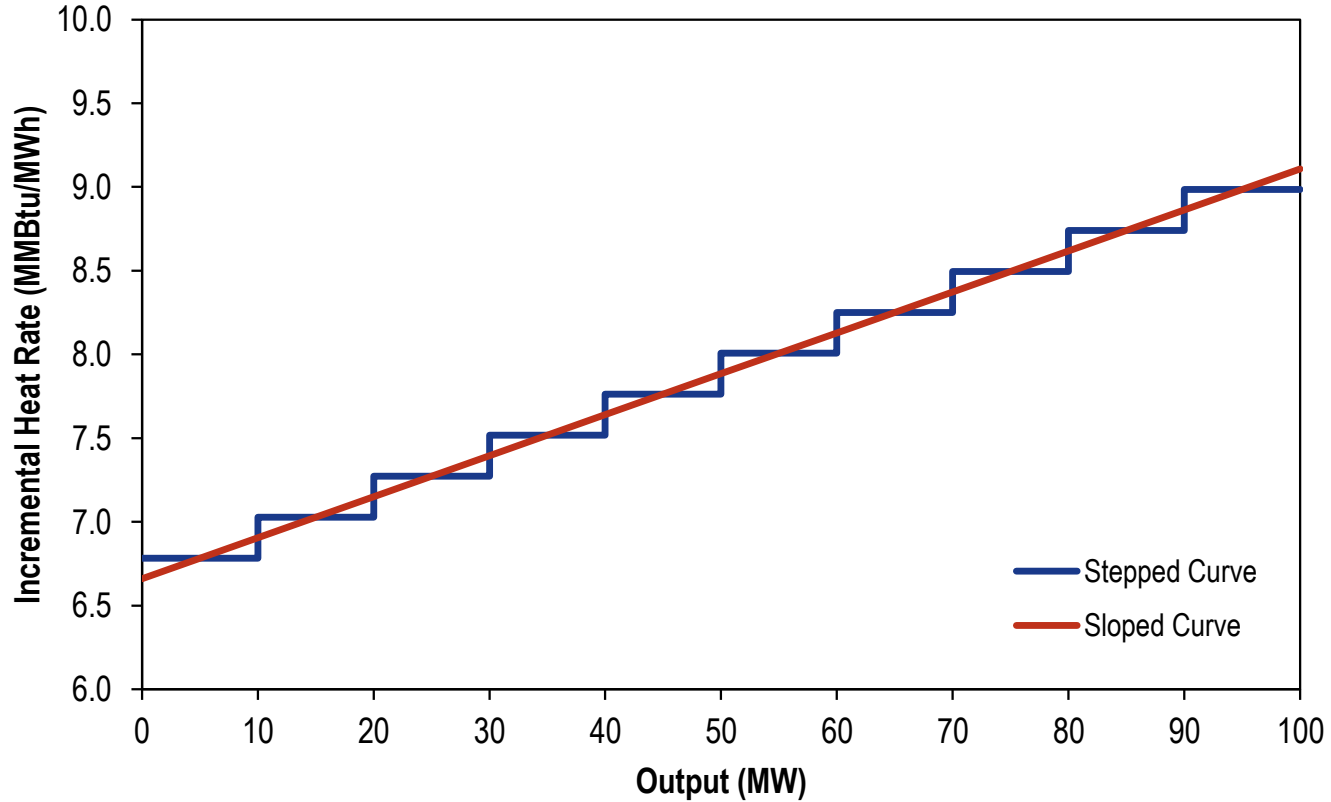
$$H'(MW) = 2 \times X_2 \times MW + X_1$$

- **When a stepped function is used, the incremental heat rate function is:**

$$H'(MW_i) = \frac{H(MW_i) - H(MW_{i-1})}{MW_i - MW_{i-1}}$$

  - **Where H(MW) is the heat input curve.**

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Incremental Heat Rate Curve

Incremental Heat Rate Curve

- **The shape of the offer curve (sloped or stepped) is selected by Market Participants in Markets Gateway.**

- **Selecting the incorrect shape in Markets Gateway results in:**

  - **Understatement when incremental heat rate curve is calculated as stepped and selected as sloped in Markets Gateway.**

  - **Overstatement (penalty) when incremental heat rate curve is calculated as sloped and selected as stepped in Markets Gateway.**

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Incremental Offer Curve Shapes

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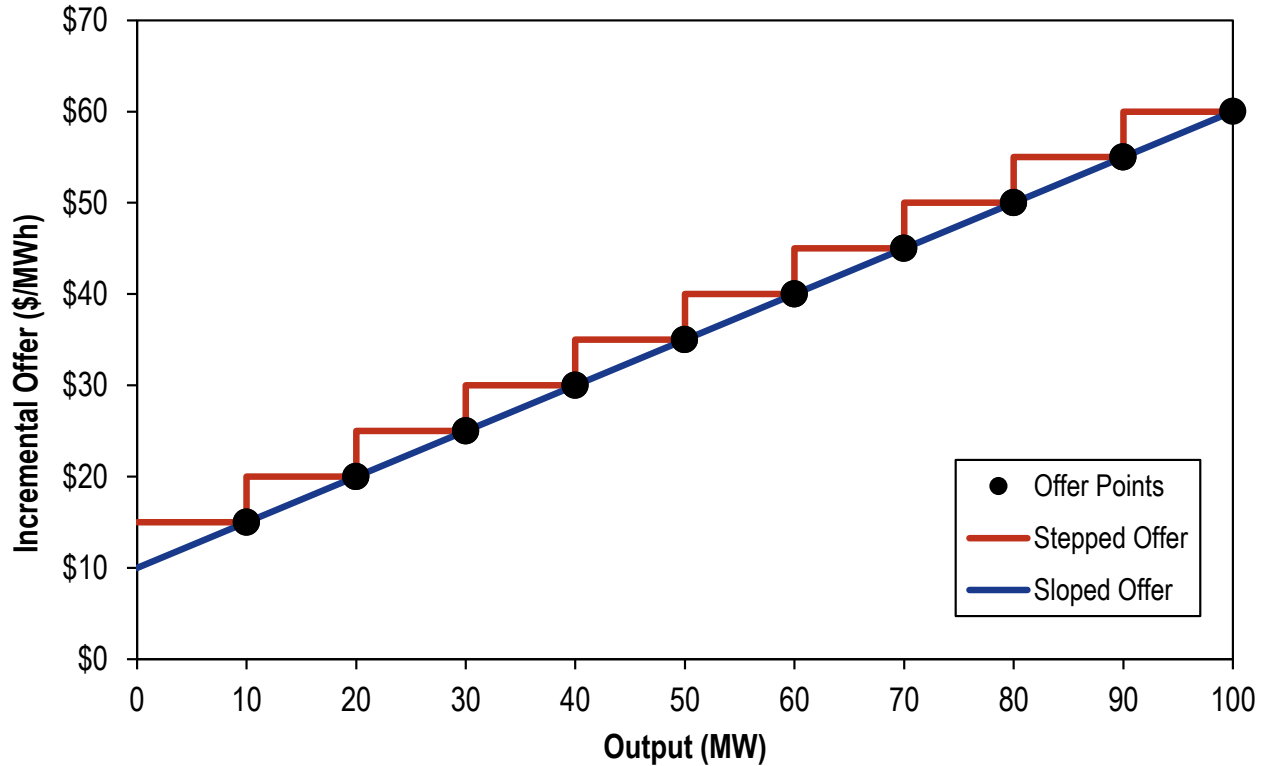
Incremental Cost Equation

- **Incremental Cost**

$$C'(MW) = H'(MW) \times \left[FC(MW) + VOM_{fuel}(MW) + EC(MW)\right] + VOM_{output}(MW) + OC(MW)$$

where:

$C'(MW)$ represents the short run marginal cost curve for the unit, varying with the MW output of the unit, in \$/MWh.

$H'(MW)$ is the incremental heat rate curve at MW, in MMBtu/MWh.

FC is the fuel cost at MW, in \$/MMBtu.

$VOM(MW)$ is the sum of the variable operating cost and the maintenance adder at MW, in \$/MMBtu. VOM can be included either in \$/MMBtu (VOM_{fuel}) or in \$/MWh (VOM_{output}).

$EC(MW)$ is the cost of emission credit allowances at MW, in \$/MMBtu.

$OC(MW)$ is the opportunity cost at MW, as defined in Section 12 of Manual 15, in \$/MWh.

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Manual 15 Incremental Cost Equations

- **Manual 15 lacks a section covering the calculation of incremental heat rates and incremental cost.**
  - **Appendix is incorrect.**
- **Starting the sloped incremental offer curves with a zero MW step makes the different no load calculations in Manual 15 unnecessary.**

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Manual 15 No Load Cost Equations

1. **Stepped:**

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

2. **Sloped if VOM is in $/MMBtu**

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

3. **Sloped if VOM is in $/ hour**

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

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Manual 15 No Load Cost Equations

- **Only equation 1 is needed, even for sloped offers.**
  - **Note: Formula needs to be updated to include hourly VOM cost.**
- **Sloped offers need to be calculated and submitted starting at zero MW.**
- **Multiple penalties have been assessed because sloped offers did not start at zero MW and equation 1 was used in the no load cost calculation.**

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Manual 15 No Load Cost Equations

- **Starting the incremental offer at eco min rather than zero results in a overstatement of the incremental cost.**

- **The no load adjustments in Manual 15 subtract from the no load that overstatement so the total cost of the unit is not overstated.**
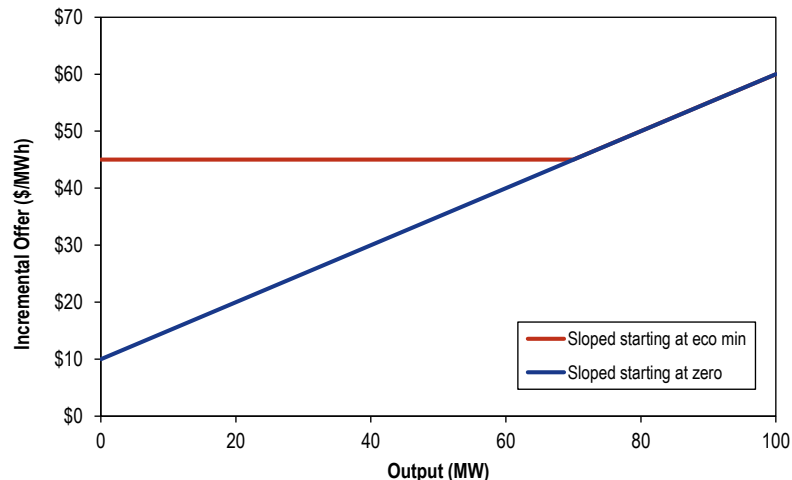
Block Loaded Offers

- **Block loaded incremental offers are calculated using average heat rates and not incremental heat rates.**

- **Average heat rate or referred just as heat rate is the efficiency of the unit at full load.**

- **The average heat rate is typically calculated by adding the total MMBtu consumed during a given period divided by the total MWh produced during the same period.**

- **It can also be calculated as the total heat input derived from the heat input curve divided by full output.**

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Block Loaded Offers

- **Using this heat input curve:**

  Heat Input Curve
  $$H(MW) = 0.1224 \times MW^2 + 6.66 \times MW + 310$$

- **The resulting average heat rate is 10.98 MMBtu/MWh.**

- **Higher than the incremental heat rate curve.**

- **That is because block loaded offers include the entire heat input (not just the incremental heat input above zero MW), they include the no load heat and therefore the no load cost.**

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Recommendations

- **Include clear equations for incremental heat rates and incremental offers in Manual 15.**

- **Include clear equations for no load cost in Manual 15.**

- **Allow and require the use of block loaded offers for units that operate that way.**

- **Fix the tariff definitions.**

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MMU Cost Offer Technical Guide

- **The MMU drafted a cost-based offer technical guide to document the equations that Manual 15 is lacking.**

- **The purpose of the guide is to:**
  - **Clarify existing Manual 15 (PJM Cost Development Guideline) language.**
  - **Provide clear equations for the calculation of accurate cost-based offers.**
  - **Include detailed, easy to follow examples.**
  - **Help prevent mistakes in submitting offers for thermal units.**

- **http://www.monitoringanalytics.com/reports/Technical References/references.shtml**

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