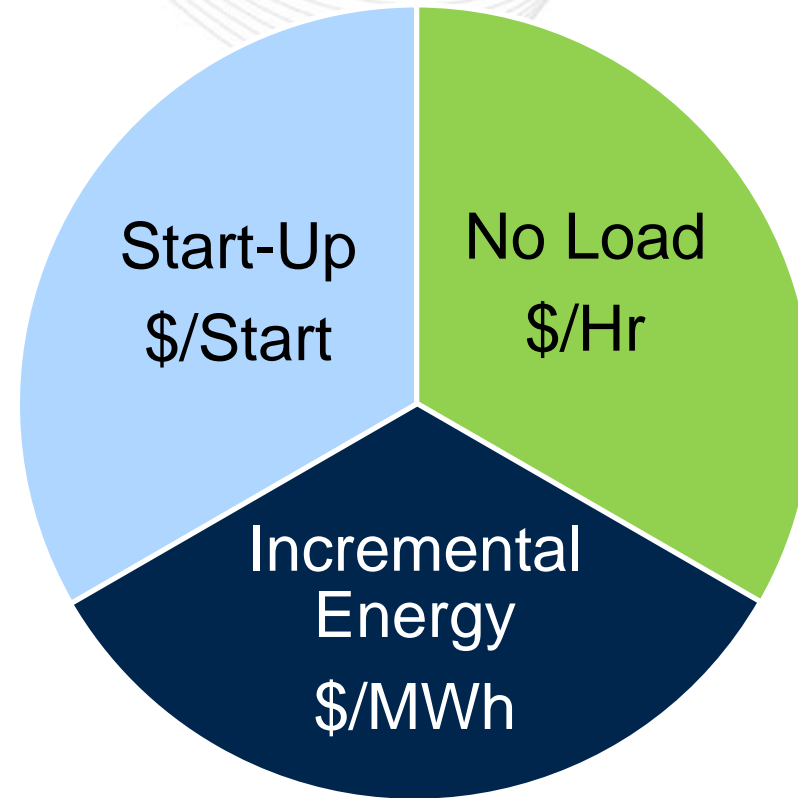


# Cost Offer Development

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Performance Compliance  
December 16, 2020

- Market Power Mitigation
  - 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.



## Total Fuel Related Costs

Fuel

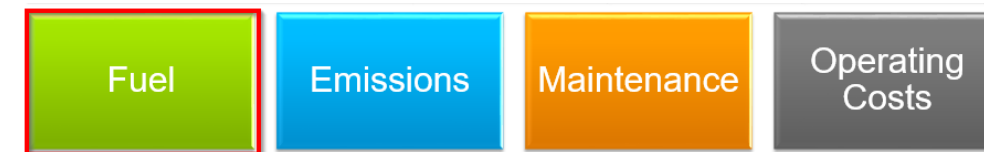
Emissions

Maintenance

Operating  
Costs

*Total Fuel Related Costs = Fuel Costs + SO<sub>2</sub> Allowance Cost  
+ CO<sub>2</sub> Allowance Cost + NO<sub>x</sub> Allowance Cost  
+ Maintenance Adder + Operating Costs*

- Basic Fuel Cost – The cost of commodity calculated as stated in the Market Sellers' Fuel Cost Policy (excluding fixed lease expenses)
- Fuel costs are a function of commodity cost, heat input, and performance factor
- Fuel costs are included in the calculations of start-up, no load, and the incremental energy offers
- Separate cost offers for each available fuel type must be created



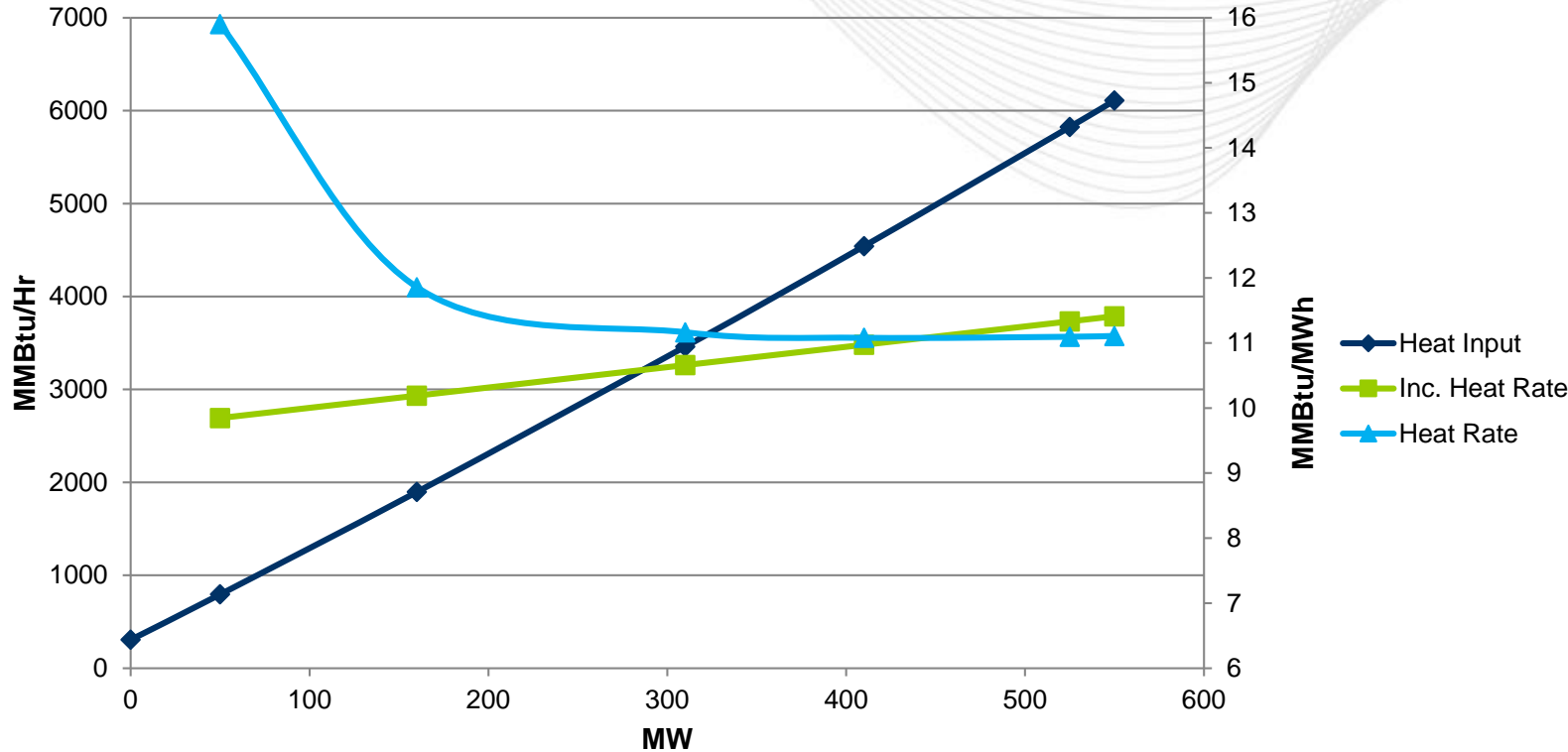
Fuel

Emissions

Maintenance

Operating  
Costs

- Heat Input equals a point on the heat input curve (MMbtu/hr) describing the resource's operational characteristics for converting the applicable fuel input (MMBtu) into energy (MWh).
  - Typically obtained via plant performance testing or from the original equipment manufacturer
  - Also referred to as the input-output function
- Heat Rate equals the MMBtu content of the heat input divided by the MWh of power output.
  - Typically a measure of efficiency
- Incremental heat rate is the relationship between an additional MW of output and the heat input necessary to produce it.
  - Typically used to create incremental energy offers
  - Slope of the input/output curve (Heat Input curve)



Output	Heat Input	Inc. HR	HR
0	306.74	9.69	
50	795.12	9.85	15.90
160	1897.08	10.19	11.86
310	3460.75	10.66	11.16
410	4542.29	10.97	11.08
525	5824.73	11.33	11.09
550	6109.33	11.41	11.11

Heat Input:  $y = Ax^2 + Bx + C$   
 $y = 0.001564x^2 + 9.6894x + 306.744$

Incremental Heat Rate:  $y = 2Ax + B$   
 $y = 0.003128x + 9.6894$

Heat Rate:  $y = \frac{\text{Heat Input}}{\text{MW}}$

- Heat Input equation incorporates no load in the curve (Point "C")
- Inc. HR does not capture no load and must be accounted for separately
- Heat Rate is a measure of efficiency

- User to enter into MIRA:
  - a heat input curve by supplying a set of input and output data points
  - Or, the user can supply the coefficients to a polynomial that defines the incr. heat rate curve
- Market Seller is responsible for keeping up to date
- Updated as stated in Fuel Cost Policy (At least annually)

Schedule ID	1
Schedule Name	2X1 Gas
Schedule Description	2 CTs and 1 ST gas fired
Performance Factor	1.0000000000
+ Add Output Range	

Output Range (MW)		Heat Input Polynomial Coefficients	Fuel Shares		Actions
From	To		Energy Source	Share	
0.0	100.0	$X^0$ <input type="text"/> $X^1$ <input type="text"/> $X^2$ <input type="text"/> $X^3$ <input type="text"/>	Fuel 1: NG <input type="text"/> Fuel 2: [Select One] <input type="text"/> Fuel 3: [Select One] <input type="text"/>	<input type="text"/>	<input type="button" value="🗑️"/>
100.1	200.0	$X^0$ <input type="text"/> $X^1$ <input type="text"/> $X^2$ <input type="text"/> $X^3$ <input type="text"/>	Fuel 1: NG <input type="text"/> Fuel 2: [Select One] <input type="text"/> Fuel 3: [Select One] <input type="text"/>	<input type="text"/>	<input type="button" value="🗑️"/>
200.1	210.0	$X^0$ <input type="text"/> $X^1$ <input type="text"/> $X^2$ <input type="text"/> $X^3$ <input type="text"/>	Fuel 1: NG <input type="text"/> Fuel 2: [Select One] <input type="text"/> Fuel 3: [Select One] <input type="text"/>	<input type="text"/>	<input type="button" value="🗑️"/>

\*Note: Cost offers >\$1,000 are screened using most current COA data



- Performance Factor is the calculated ratio of actual fuel burn to either theoretical fuel burn (design heat input) or other current tested heat input

$$\text{Performance Factor} = \frac{\text{Total Actual Fuel Consumed}}{\text{Total Theoretical Fuel Consumed}}$$

- Factors may change actual fuel consumed such as
  - Unit age or modification
  - Changes in fuel properties
  - Seasonal ambient conditions
- Annual update required by Fuel Cost Policy entered into COA

\*Note: Cost offers >\$1,000 are screened using most current COA data

- Fuel Cost Policy contains the methodology of determining the cost of  $\text{SO}_2/\text{CO}_2/\text{NO}_x$  EAs
- Market Participants are to submit Emissions via COA to PJM and MMU Annually for PJM review and approve
  - Expires December 31 of each year
- Must be approved by PJM before it may be used

\*Note: Dual fuel units should use different EA factors based on the  $\text{SO}_2/\text{CO}_2/\text{NO}_x$  emitted for each particular fuel or fuel mix



- A VOM Template is submitted by the Market Participant via SharePoint to PJM and MMU Annually for PJM review and approve
  - Separate process from Fuel Cost Policy Review
  - Expires December 31 of each year
- PJM's VOM Template includes separate sheets for operating costs and maintenance costs
- Must be approved by PJM before used in cost-based offers



- Maintenance Adders may be specified as:
  - \$/Start, \$/Hour, \$/MMBtu, or \$/MWh
- VOM value used in cost offers cannot exceed approved value

Offer	\$/MMBtu	\$/Hr	\$/MWh
Start Cost	Yes	Yes	No
No Load Cost	Yes	Yes; either No load OR Incremental	No
Incremental Energy	Yes	Yes; either No load OR Incremental	Yes



# Maintenance Cost Template Example

- Maintenance Tab
- 10/20 year history
  - Previous years escalated based on the Handy-Whitman index
- Immature units:
  - Units with neither 10 years history or 50,000 operating hours
  - To only include # of operating years < 10 (Section 1.8 request)

SECTION 2: TOTAL HISTORICAL MAINTENANCE COST									
INSTRUCTIONS:		Please select from the drop down menu whether you are using a 10 or 20 year maintenance history and fill out the table below. For immature units, please fill out table below with actual available maintenance history. <b>Note: If selecting Annual MWh, please only include hours with positive net MWhs.</b>							
Select Maintenance History:		Actual < 10		Operating History Units:		Annual MWh			
		Maintenance History		Operating History		2020		781 1,000	
Year		Annual \$		Annual MWh		Handy Whitman			
						YEAR INDEX ESCALATION FACTOR			
2019	\$	-				2019	760	1,028	
2018						2018	745	1,048	
2017						2017	711	1,098	
2016						2016	714	1,094	
2015						2015	700	1,116	
2014						2014	672	1,162	
2013						2013	653	1,196	
2012						2012	645	1,211	
2011						2011	631	1,238	
2010						2010	604	1,293	
2009						2009	578	1,351	
2008						2008	596	1,310	
2007						2007	546	1,430	
2006						2006	515	1,517	
2005						2005	493	1,584	
2004						2004	465	1,680	
2003						2003	441	1,771	
2002						2002	438	1,783	
2001						2001	425	1,838	
2000						2000	415	1,882	
Total Historical Maintenance Cost				\$ 0.00					
Total Annual MWh				-					
Per Unit Maintenance Cost				#DIV/0!					
2020 MARKET SELLER REQUESTED MAINTENANCE ADDER									
MAINTENANCE ADDER:		#DIV/0!		/ MWh					



# Operating Costs Template Example

- Operating Costs Tab
- 1- 5 year history
  - For units using >1 year of history, the previous years are escalated using the Handy-Whitman index

SECTION 2: TOTAL HISTORICAL OPERATING COST					
INSTRUCTIONS:		Please fill out the table below using up to 5 years history. If less than 1 year of data entered, then please indicate length in Cell D58 as a note (i.e. 6 month rolling average). <b>Note: If selecting Annual MWh, please only include hours with positive net MWhs.</b>			
		Operating History Units:		Annual MWh <input type="button" value="v"/>	
		Operating Cost History		2020 781 1.000	
		Operating History		Handy Whitman	
Year		Annual \$		YEAR INDEX ESCALATION FACTOR	
2019	\$	-		2019	760 1.028
2018				2018	745 1.048
2017				2017	711 1.098
2016				2016	714 1.094
2015				2015	700 1.116
Total Historical Operating Cost		\$	0.00		
Total Annual MWh					
Per Unit Operating Cost		#DIV/0!	/MWh		
2020 MARKET SELLER REQUESTED OPERATING COST ADDER					
OPERATING COST ADDER:		#DIV/0!	/MWh		

Operating Costs include but are not limited to:

- Water
- Chemicals
- Consumables
- Transportation
- Non-Fuel Pipeline Charges





- Start-up Costs
  - the unit costs to bring the boiler, turbine and generator from shutdown conditions to the point after breaker closure
  - 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
  - can vary and be categorized in three unit temperature conditions: hot, intermediate, and cold
  - incurred once each time the unit operates regardless of the period of operation



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

- 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.
- 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 Additional Labor Cost – Additional labor costs for startup required above normal station manning levels.

- No Load Fuel
  - (MMBtu/hour) is the total fuel to sustain zero net output MW at synchronous generator speed
- No Load Cost
  - (\$/hour) – The hourly cost required to create the starting point of a monotonically increasing incremental offer curve for a generating unit.
    - Can be calculated using No Load fuel
    - The calculated No Load Cost may have to be adjusted to ensure that the slope of the Generator Offer Curve is monotonically increasing.



# No Load Example – Steam Unit

- 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:

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

Performance Factor (PF) = 1.02  
 Total Fuel Related Cost (TFRC) = \$14.00/MMBtu  
 VOM = \$0.15/MMBtu

- Then at zero output is No load Fuel = 306.744 MMBtu/Hr
- The initial estimate of a unit's No Load Cost (\$/Hr) is:

$$\begin{aligned} \text{No Load Cost (\$/Hr)} &= (\text{No Load Fuel} * PF * TFRC) \\ &= 306.744 \text{ MMBtu/hr} * 1.02 * \$14.00/MMBtu = \$4,380/hr \end{aligned}$$

- The unit's Cost Curve must be developed to determine if adjustments are needed for the unit's No-Load Cost.
- Total Operating Cost is calculated by:

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

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

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

- 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.

$$\text{Incremental Cost} = \frac{11,476 - 4,380}{50 - 0} = \$141.91/MWh$$

Output (MW)	Heat Input (MMBtu/hr)	Total Operating Cost (\$/hr)	Incremental Cost (\$/MWh)
50	795.12	11476	141.91
160	1897.08	27381	144.59
310	3460.75	49949	150.46
410	4542.29	65559	156.10
525	5824.73	84068	160.95
550	6109.00	88171	164.11

- The unit's Incremental Cost (\$/MWh) at various output levels can also be determined by using the incremental heat rate curve

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

- The No Load Cost is calculated by subtracting the incremental cost 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.

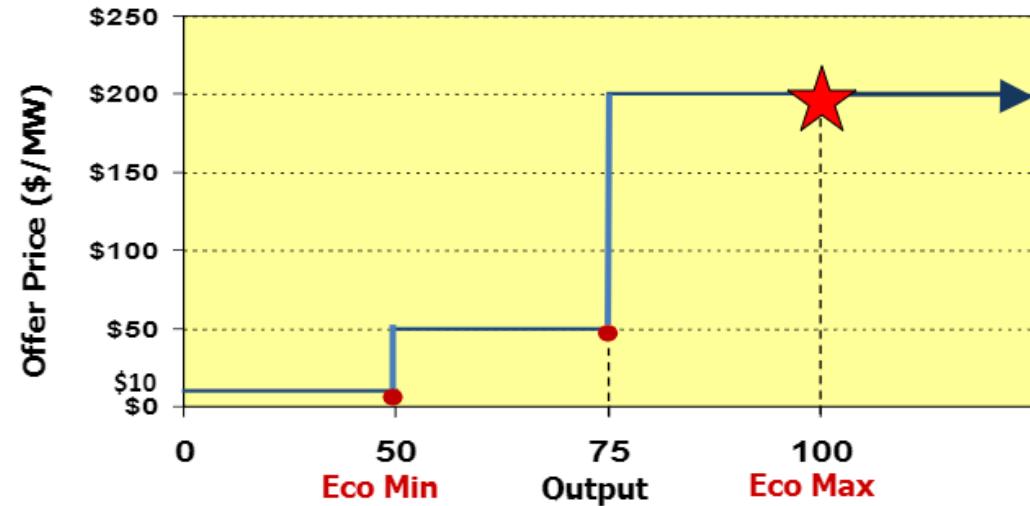
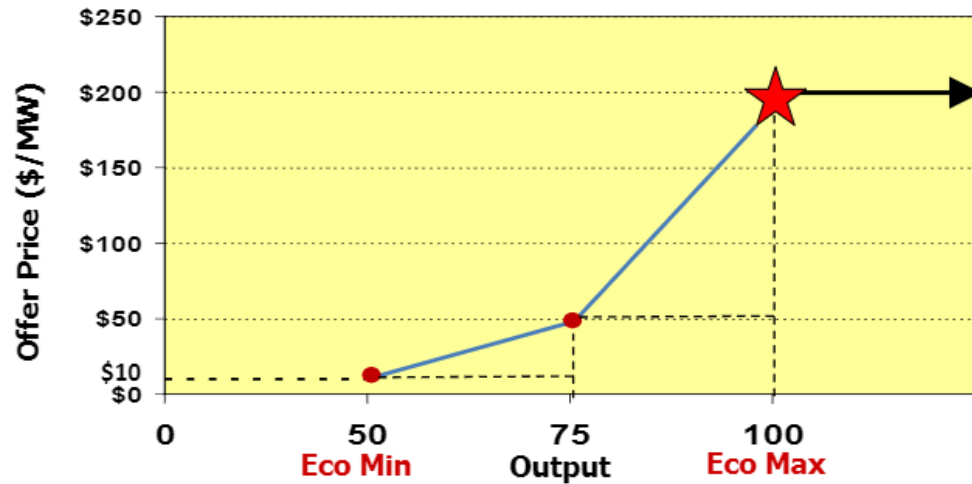
$$\begin{aligned} \text{No Load Cost} \left( \frac{\$}{Hr} \right) &= (\text{Eco Min Heat Input} * PF * (TFRC + VOM)) - (\text{Eco Min Incr. Cost} * \text{Eco Min MW}) \\ &= \left( 795.12 \frac{MMBtu}{Hr} * 1.02 * \left( \frac{\$14}{MMBtu} + \$ \cdot \frac{015}{MMBtu} \right) \right) - \left( \frac{\$142.10}{MWh} * 50 MW \right) = \$4,370.97/Hr \end{aligned}$$

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

- 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 incremental heat rate method, user must select "Use Bid Slope" when entering cost information into Markets Gateway.

- Slope Offer Curve
  - “Use Bid Slope” in Markets Gateway
  - Must select in Day-Ahead offer
  - No 0 MW point defined
    - The first point describing the Economic Minimum Limit of the unit is extended to Y-axis

- Block Offer
  - Step function



- Incremental energy cost
  - (\$/MWh) the cost per MWh to produce all of the energy segments above the Economic Minimum level
  - Calculated by summing the cost of each segment of energy in the unit's incremental cost curve up to the generation level
  - No-Load Costs are not included in the incremental costs
  - Must be monotonically increasing



## Total Production Cost

Start-Up Cost + Run Hours \* Operating Cost

- Represents the cost of starting a unit & operating it over a period of time

## Operating Cost

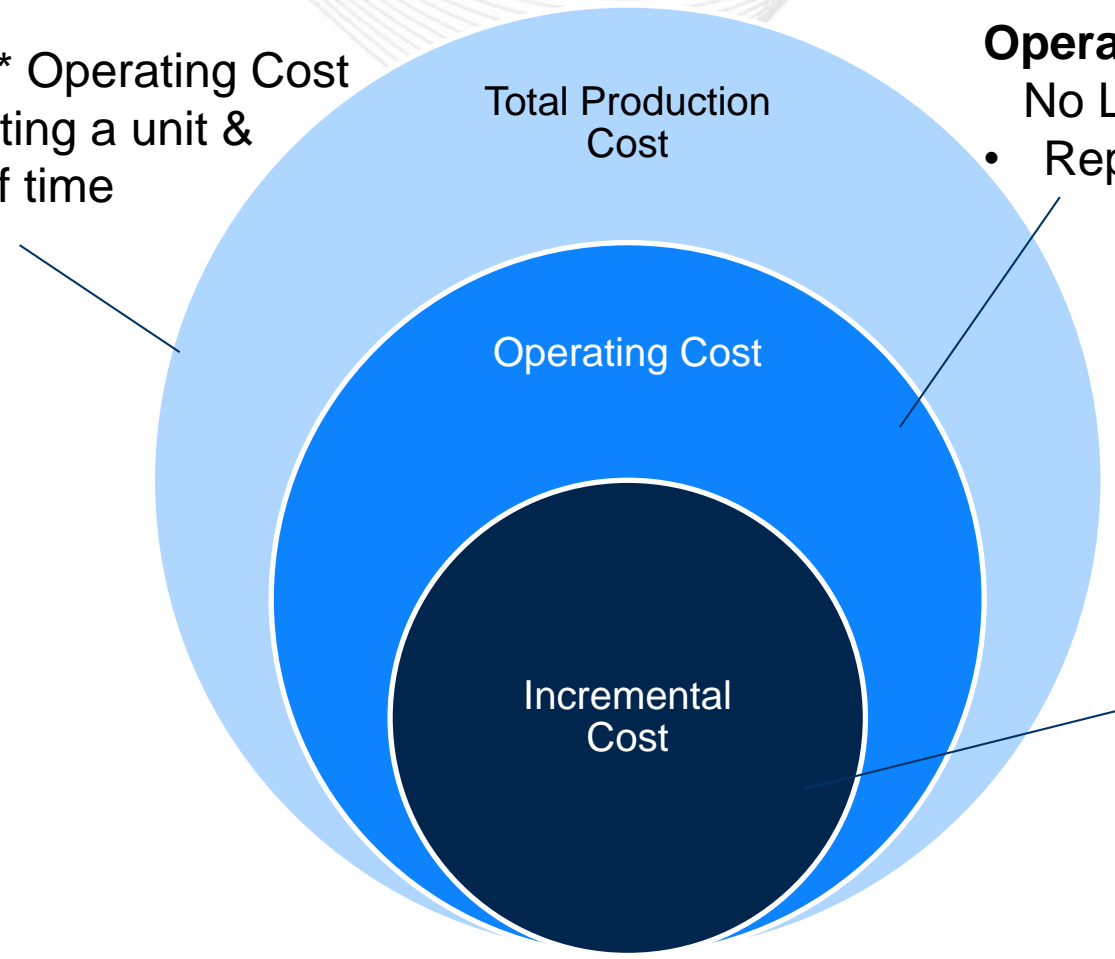
No Load Offer + Incremental Offer Curve

- Represents the hourly production cost

## Incremental Cost

Incremental Offer Curve

- Represents the cost to generate the next MW





- Specific details for unit types can be found in the following sections:
  - Section 3 – Nuclear
  - Section 4 – Fossil/Steam
  - Section 5 – Combined Cycle (CC)
  - Section 6 – Combustion Turbine (CT) and Diesel
  - Section 7 – Hydro
  - Section 9 – Wind Units
  - Section 10 – Solar Units
  - Section 11 – Energy Storage Units
  - Attachment B: No Load Calculation Examples by Technology

# Appendix

- 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.

- VOM Template:

<https://pjm.com/-/media/markets-ops/energy/fuel-cost-policy/vom-template.ashx?la=en>

- Fuel Cost Policy Templates

<http://www.monitoringanalytics.com/tools/tools.shtml>

- Markets Gateway User Guide

<https://www.pjm.com/~media/etools/markets-gateway/markets-gateway-user-guide.ashx>

- MIRA User Guide

[http://www.monitoringanalytics.com/tools/docs/MIRA\\_User\\_Guide\\_20160315.pdf](http://www.monitoringanalytics.com/tools/docs/MIRA_User_Guide_20160315.pdf)

- COA Module User guide

[http://monitoringanalytics.com/tools/docs/MIRA\\_Cost\\_Offer\\_Assumptions\\_User\\_Guide\\_20170602.pdf](http://monitoringanalytics.com/tools/docs/MIRA_Cost_Offer_Assumptions_User_Guide_20170602.pdf)