No-Load Definition: Educational Document

No-Load: Past and Present

PJM began as a power pool where generating companies agreed to centralized dispatch of their generation. PJM originally dispatched the pool using incremental cost curves developed from incremental heat rate curves and fuel cost supplied by the members. Since 1997, PJM has used incremental cost/price offers supplied by the members to dispatch the system. No-load is a portion of the cost offer that PJM uses in its calculation to determine which resources should be dispatched. (See Appendix 2)

PJM uses this information to place generation in and out of service and achieve the lowest possible overall cost for the system. No–load is one of the inputs PJM needs to minimize production costs.

The book Fundamentals of Power System Economics defines no-load cost as the theoretical cost for a unit "… to remain connected to the system while supplying non electrical power, the no-load cost represents the cost of fuel required to keep the unit running. Such a mode of operation is not possible for most thermal generating units. The no-load cost is simply the constant term in the cost curve and does not have physical meaning."[1] (See Appendix 1)

References to PJM Documents

Manual 15: Cost Development Guidelines (Manual 15) discusses no-load cost as a component of the cost based offer. [2] Manual 15 defines no-load as the "calculated cost per hour to run at zero net output". Manual 15 also provides the following guidance on how to calculate the no-load cost:

> *"Since generating units cannot normally be run stable at zero net output, the heat input may be determined by extrapolating the total heat input-output curve to zero net output. 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 input-output curve. 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."* [3]

Manual 15 also adds that "no load costs are not included in incremental costs… this cost is a dollar per hour ($/hour) rate." [4] And no-load is referenced in the discussion regarding performance factor calculation[5]. Manual 15 only addresses two unit types specific to their no-load. Combustion Turbine no-load fuel is defined as "the theoretical or actual fuel burn rate expressed in MBTU/Hr at the point of electric bus synchronization." [6] Furthermore the CT Maintenance Adder "is included directly in…no-load…" [7] The only other reference to unit specific no-load costs or fuel is for Hydro Units; simply stating that they "…do not have no-load costs." [8] Manual 15 is not explicit on how the no-load cost should be calculated for a combined cycle.

No-load costs are also referenced in the **eMKT User's guide**. "No-load cost (or price) is the hourly fixed cost (or price), expressed in $/hr, to run the generating unit at zero net output. It can include hourly no-load costs and other fixed costs." It also talks about using cost-based no-load and price based no-load and the enrollment period twice a year.

The **Open Access Transmission Tariff** mentions no-load:
> 1 Black Start Resources will be paid for testing (including their no-load costs)[9]
> 2. Generators can choose price or cost no-load and startup costs on a 6 month basis.[10]
> 3. All capacity resources shall submit a "binding offer for energy, along with startup and no load fees". [11]
> 4. Pool scheduled resources that are selected or selected and cancelled will be paid no-load costs[12]
> 5. Self scheduled units do not get no-load fees.[13]
> 6. Units get BOR to cover no-load fees when scheduled back within PJM or into the PJM region by the Transmission Provider.[14]
> 7. Operating Reserves will pay no-load costs if LMP does not.[15]
> 8. Reactive reliability will be compensated for no-load cost.[16]
> 9. If the offer price plus startup or no-load fees cannot exceed $1000/MWh[17]

Within PJM's training course PJM Generation 201, No-load Cost is defined as the "Cost per hour to maintain the boiler operating and the turbine and generator spinning at synchronous speed, but not generating any output. This is a dollars per hours ($/hr) cost."[18]

Other RTO practices regarding no-load

New York Independent System Operator (NYISO) Manual 11 Defines the operating bid as the "piecewise linear monotonically increasing cost curve. These bids are comprised of up to 20 segments. The first segment is defined by the no-load cost axis intercept ($/hr) and a slope ($/MWh). The next segments are defined by MW break point and slope ($/MWh) pairs. Different curves can be input for different schedule days.[19]

Midwest Independent System Operator (MISO): "No Load – Costs for operating a Generation Resource at zero MWs."[20]

California Energy Commission Electricity Analysis Office The No-Load Heat Rate is defined as the extrapolation of the Input-Output Curve back to the vertical axis (Input).[21]

Single Electric Market Operator (SEMO): "No Load Cost means the element of operating cost for a Generator Unit, submitted as part of Commercial Offer Data that is invariant with the level of Output and is incurred at all times when the level of Output is greater than zero"[22]

Appendix 1: Examples of different unit type no-load fuel calculations through extrapolation of the input-output curve

Example 1.1 Steam Units

This is an example steam unit heat input curve. The x-axis shows output from the steam unit in MWs and the y-axis shows the heat input of fuel in MBTU/hour. The five points on the curve show the readings taken at different levels of output. These values are provided by the OEM or are determined during the initial operational testing of the generating unit. An equation (a 2nd order polynomial) is created to "fit" the curve that the steam unit's readings appear to be making. Using this equation, the resource owner can extrapolate to the 0 MW fuel inputs, which would be the no-load or zero MW fuel.

Example Steam Unit Heat Input Curve

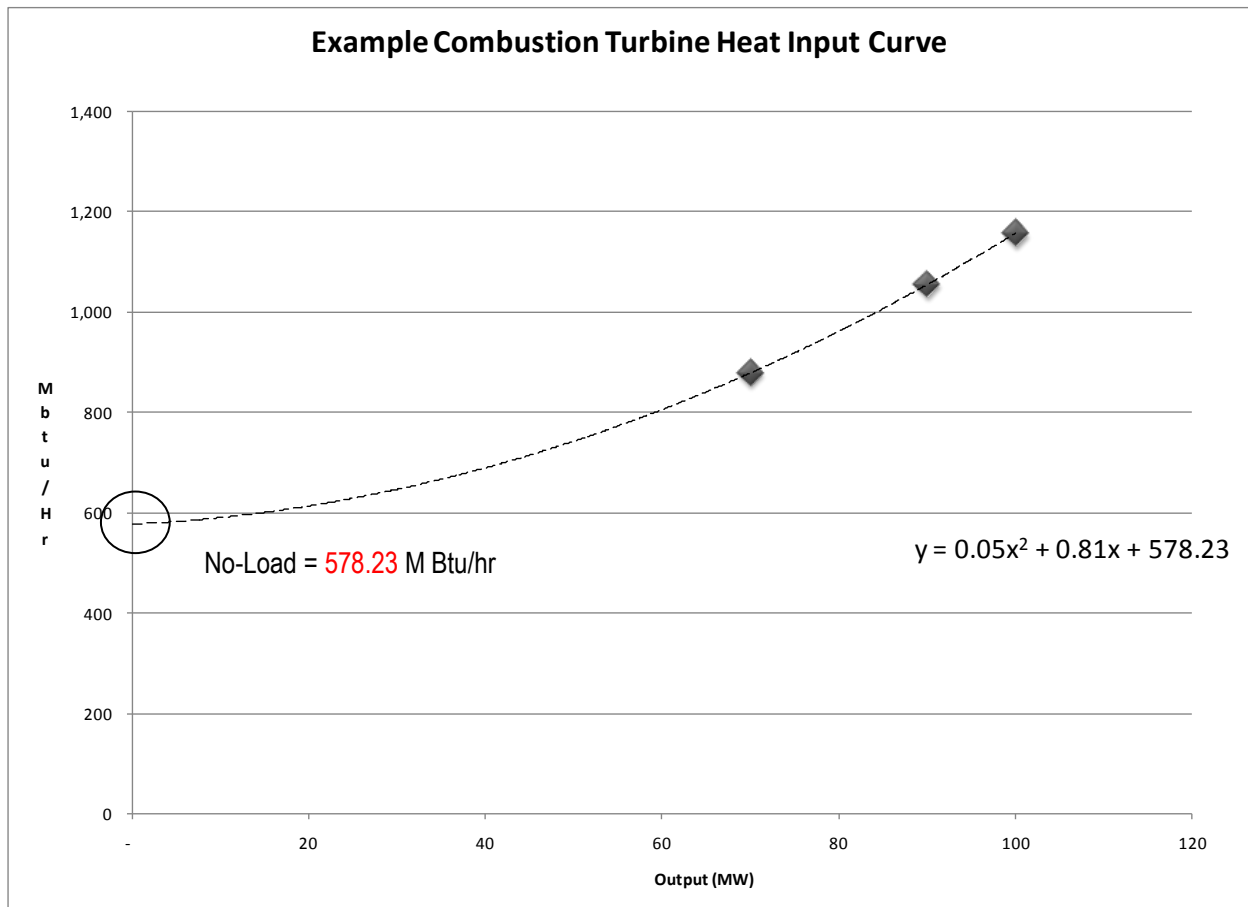$y = 0.01x2 + 8.77x + 71.83$
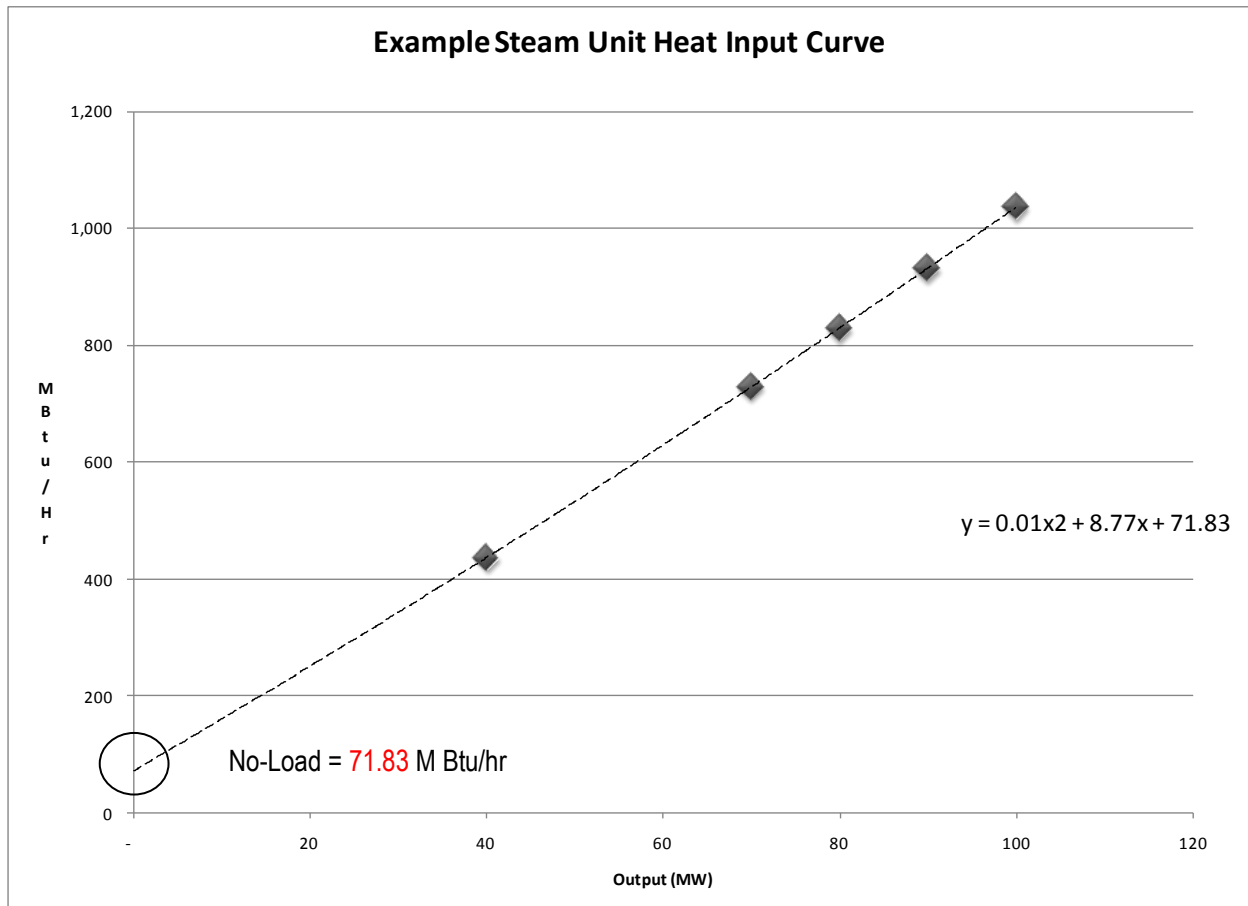
No-Load = 71.83 M Btu/hr

The table below shows the input in MBTU/hour, output in MW, heat rate at different levels of output and incremental heat rate. These numbers correspond to what is shown in the graph above. The red 71.83 MBTU/hour is the no-load fuel, which when multiplied by the fuel costs gives us the no-load cost for the cost based offer.

Steam Unit			
Output	Heat Input	Heat Rate	Incrementals
(MW)	(MBtu/hr)	(Btu/kWh)	(Btu/kWh)
0	**71.83**		
40	436.40	10,910	9,114
70	728.41	10,406	9,734
80	828.48	10,356	10,007
90	931.74	10,353	10,326
100	1,035.59	10,356	10,385

Example 1.2 Combustion Turbines

This is an example combustion turbine heat input curve. The x-axis shows output from the CT unit in MWs and the y-axis shows the heat input of fuel in MBTU/hour. The three points on the curve show the readings taken at different levels of output. These values are provided by the OEM or are determined during the initial operational testing of the generating unit. An equation (a 2nd order polynomial) is created to "fit" the curve. Using this equation the resource owner can extrapolate to the 0 MW fuel inputs, which would be the no-load or zero MW fuel.

Example Combustion Turbine Heat Input Curve

No-Load = 578.23 M Btu/hr

$$y = 0.05x^2 + 0.81x + 578.23$$

The table below shows the input in MBTU/hour, output in MW, heat rate at different levels of output and incremental heat rate. This test was done at 59 degrees, and since heat rates can change with temperature for most combustion turbines, this temperature is noted so that the reader understands that this may not be the heat rate curve or no-load levels in every

circumstance. These numbers correspond to what is shown in the points in the graph above. The red 578.23 MBTU/hour is the no-load fuel, which when multiplied by the fuel costs gives us the no-load cost for the cost based offer at 59 degrees.

Combustion Turbine

Output	Heat Input	Heat Rate	Incrementals
(MW)	(MBtu/hr)	(Btu/kWh)	(Btu/kWh)
0	**578.23**		
70	879.02	12,557	4,297
90	1,054.57	11,717	8,778
100	1,157.28	11,573	10,271
Conditions at 59F			

Example 1.3 1x1 Combined Cycle Units (Not explicit in M15)

This is an example combined cycle heat input curve with a 1x1 operation (one combustion turbine and one Heat Recovery Steam Generator or HRSG). Since Manual 15 is not explicit in how no-load should be computed for combined cycles, the extrapolation to the y-axis is left out of these graphs. Similar to steam and CT generators, the x-axis shows output from the unit in MWs and the y-axis shows the heat input of fuel in MBTU/hour. The points on the curve show the readings taken at different levels of output.

Example 1X1 Combined Cycle Heat Input Curve
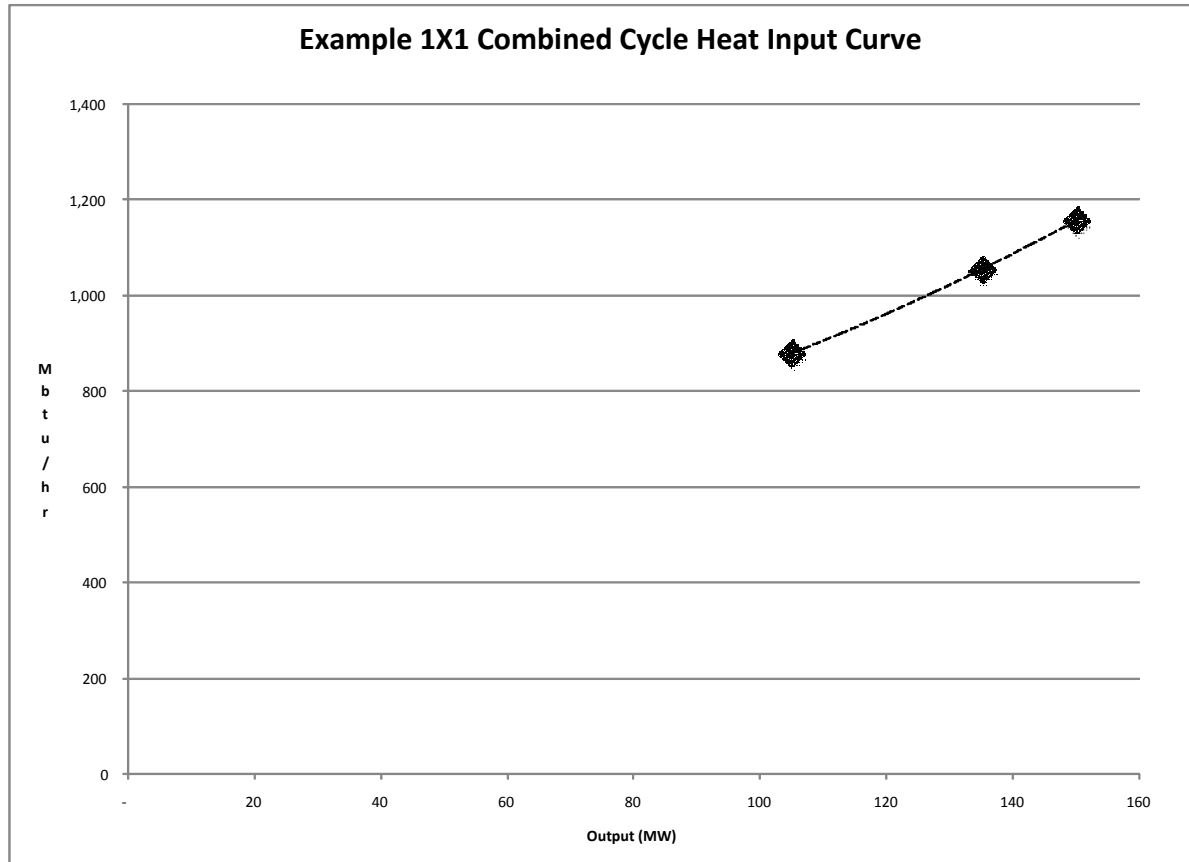
The table below shows the input in MBTU/hour, output in MW, heat rate at different levels of output and incremental heat rate. This test was done at 59 degrees, and since heat rates can change with temperature. These numbers correspond to what is shown in the points in the graph above.

Combined Cycle - 1 on 1

Output	Heat Input	Heat Rate	Incrementals
(MW)	(MBtu/hr)	(Btu/kWh)	(Btu/kWh)
0	578.23		
105	879.02	8,372	2,865
135	1,054.57	7,812	5,852
150	1,157.28	7,715	6,847
Conditions at 59F			

Example 1.4 1x2 Combined Cycle Units (Not explicit in M15)

This is an example combined cycle heat input curve with a 2x1 operation (two combustion turbines and one Heat Recovery Steam Generator or HRSG). The points on the curve show the readings taken at different levels of output.
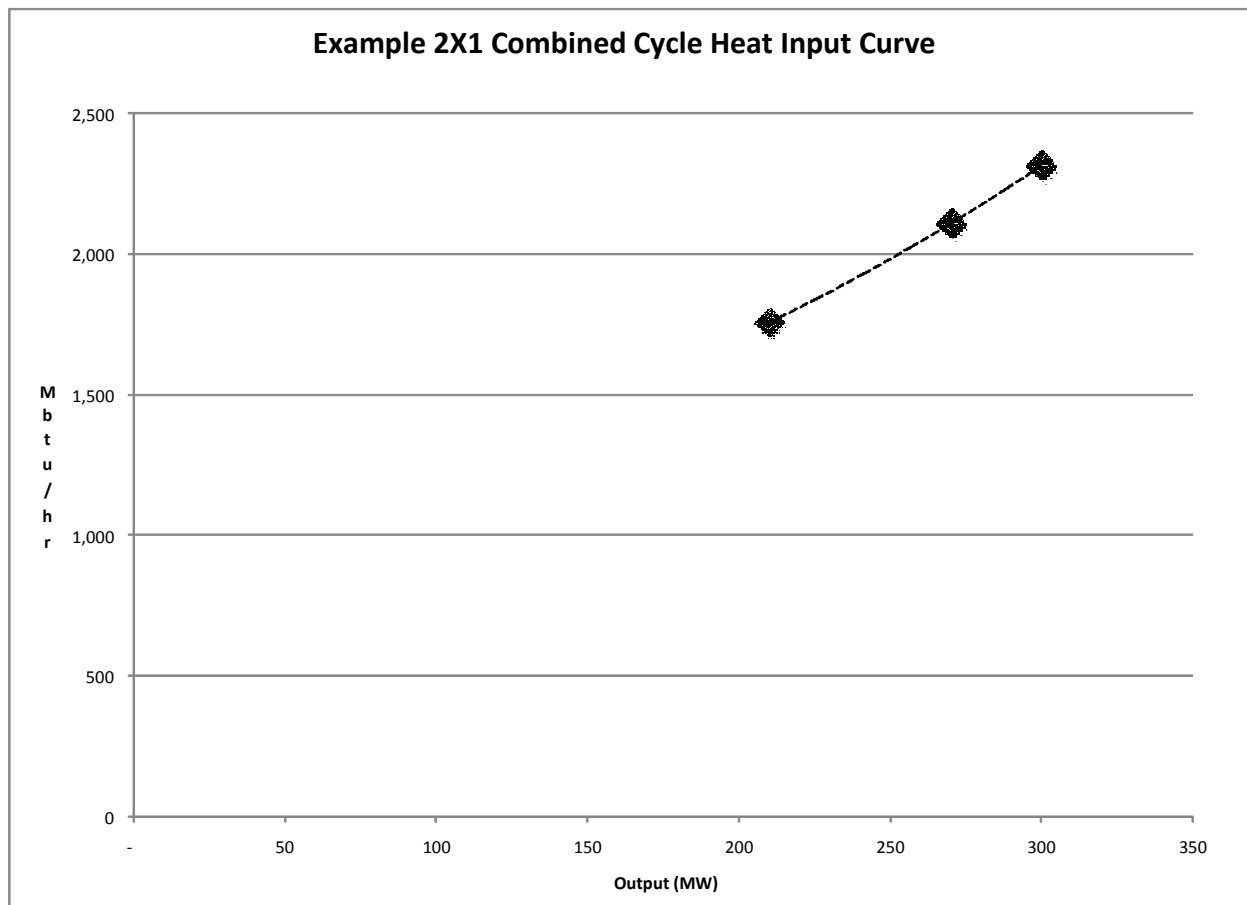
The table below shows the input in MBTU/hour, output in MW, heat rate at different levels of output and incremental heat rate. These numbers correspond to what is shown in the points in the graph above.

Combined Cycle - 2 on 1

Output	Heat Input	Heat Rate	
(MW)	(MBtu/hr)	(Btu/kWh)	
0	1,156.50		
210	1,758.04	8,372	
270	2,109.14	7,812	
300	2,314.56	7,715	
Conditions at 59F			

Appendix 2: Use of no-load by PJM

PJM calculates hourly production cost and total production cost (the cost to operate a unit for a particular time). The following example is used to illustrate the use of no-load costs in economic dispatch. Table 1 shows representative units[23] and inputs to their cost offer.

Table 1: Three example units

	Unit Stan		Unit Tom		Unit Laura	
Fuel Cost ($/mmBtu)	$	2	$	20	$	5
Start Cost ($/start)	$	3,448	$	5,782	$	11,565
No Load ($/hour)	$	144	$	11,565	$	2,891
Cost Curve	MW	Inc Price	MW	Inc Price	MW	Inc Price
Segment 1	40	$ 18	70	$ 86	105	$ 14
Segment 2	80	$ 20	90	$ 176	135	$ 29
Segment 3	100	$ 21	100	$ 205	150	$ 34
Eco Max MW	100		100		150	
Eco Min MW	40		70		105	
Minimum Runtime (hours)	1		1		1	

PJM takes these generator inputs and calculates hourly production costs using the following equations:

$$\text{Cost at Min} = \text{No} - \text{Load} + \text{1st incremental to min}$$

$$\text{Hourly Production Cost at Eco} - \text{Max} = \text{No} - \text{Load} + \text{1st Segment} + \text{2nd Segment} + \text{3rd Segment}$$

$$\text{Operating Rate} = \frac{\text{Hourly Production Cost at Eco} - \text{Max}}{\text{Eco Max MW}}$$

Table 2: Hourly Costs for three example units

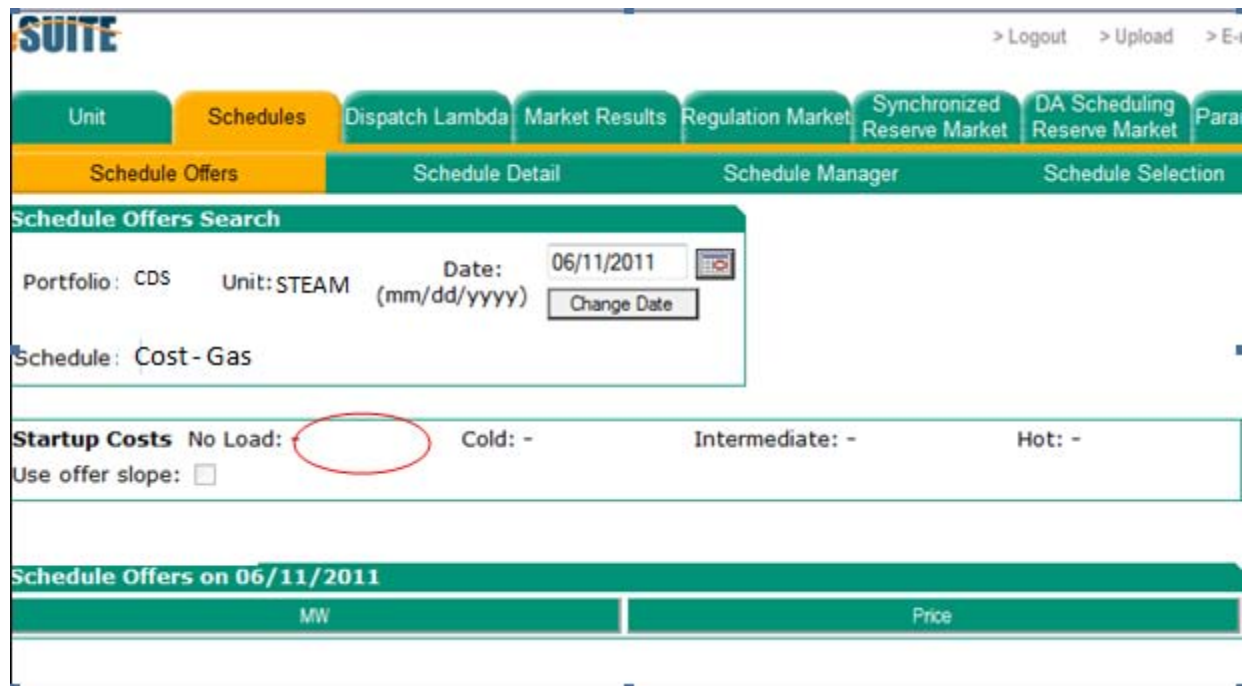|	Unit Stan	Unit Tom	Unit Laura
Eco Max	100	100	150
No Load ($/hour)	$ 144	$ 11,565	$ 2,891
Cost 0-Min (1st Segment)	$ 729	$ 6,016	$ 1,504
Cost1st Segment to 2nd Segment	$ 784	$ 3,511	$ 878
Cost 2nd Segment to 3rd Segment	$ 414	$ 2,054	$ 514
Cost at Min	$ 873	$ 17,580	$ 4,395
Hourly Cost at Eco-Max	$ 2,071	$ 23,146	$ 5,786
Operating Rate	$ 20.71	$ 231.46	$ 38.58

PJM dispatches by minimizing production cost: Hourly Production Cost and Total Production Cost. In the above table we see each unit's hourly production cost. In the table below we see the range of cost from running the unit on its eco min versus running the unit for its eco-max for the duration of its minimum runtime.

Table 3: Different total costs

	Unit Stan	Unit Tom	Unit Laura
Min Cost	$ 4,320.64	$ 23,362.70	$ 15,959.70
Max Cost	$ 5,519.02	$ 28,927.90	$ 17,351.00

As we can see, each unit can have a range of possible costs depending on dispatch, start cost, no load and segmented energy costs.

Appendix 3: Where no load is entered into eMKT

No Load is entered on the Schedules – Schedules Offers page in eMKT.

[1] Kirschen, Daniel Sadi and Strbac, Goran. *Fundamentals of Power Economics.* West Sussex, England: John Wiley and Sons, 2004. Print. page 84

[2] M15: Section 1.7 and Section 2.5.1

[3] M15: Section 2.5.1

[4] M15: Section 1.7.3-1.7.4

[5] M15: Section 2.2.3 and 2.5.2

[6] M15: Section 6.1

[7] M15: Section 6.3.2

[8] M15: Section 7.1

[9] OATT Page 590

[10] OATT page 1699

[11] OATT Page 1706 and OATT Page 1709

[13] OATT Page 1711

[14] OATT Page 1722 OATT Page 1745

[16] OATT 1769

[17] OATT Page 1883

[18] Scheduling Process in eMKT, Page 54-55

[19] http://www.nyiso.com/public/webdocs/documents/manuals/operations/dayahd_schd_mnl.pdf

[20] MISO FAQ for RSG

[21] http://nodal.ercot.com/docs/tntarc/mo/CAHeatRates.pdf

[22] The Single Electricity Market (SEM) is the wholesale electricity market operating in the Republic of Ireland and Northern Ireland.

[23] All characters appearing in this work are fictitious. Any resemblance to real persons, living or dead is purely coincidental.