No-Load and Incremental Energy Offer Numerical Examples

Tom Hauske
Performance Compliance
Cost Development Subcommittee
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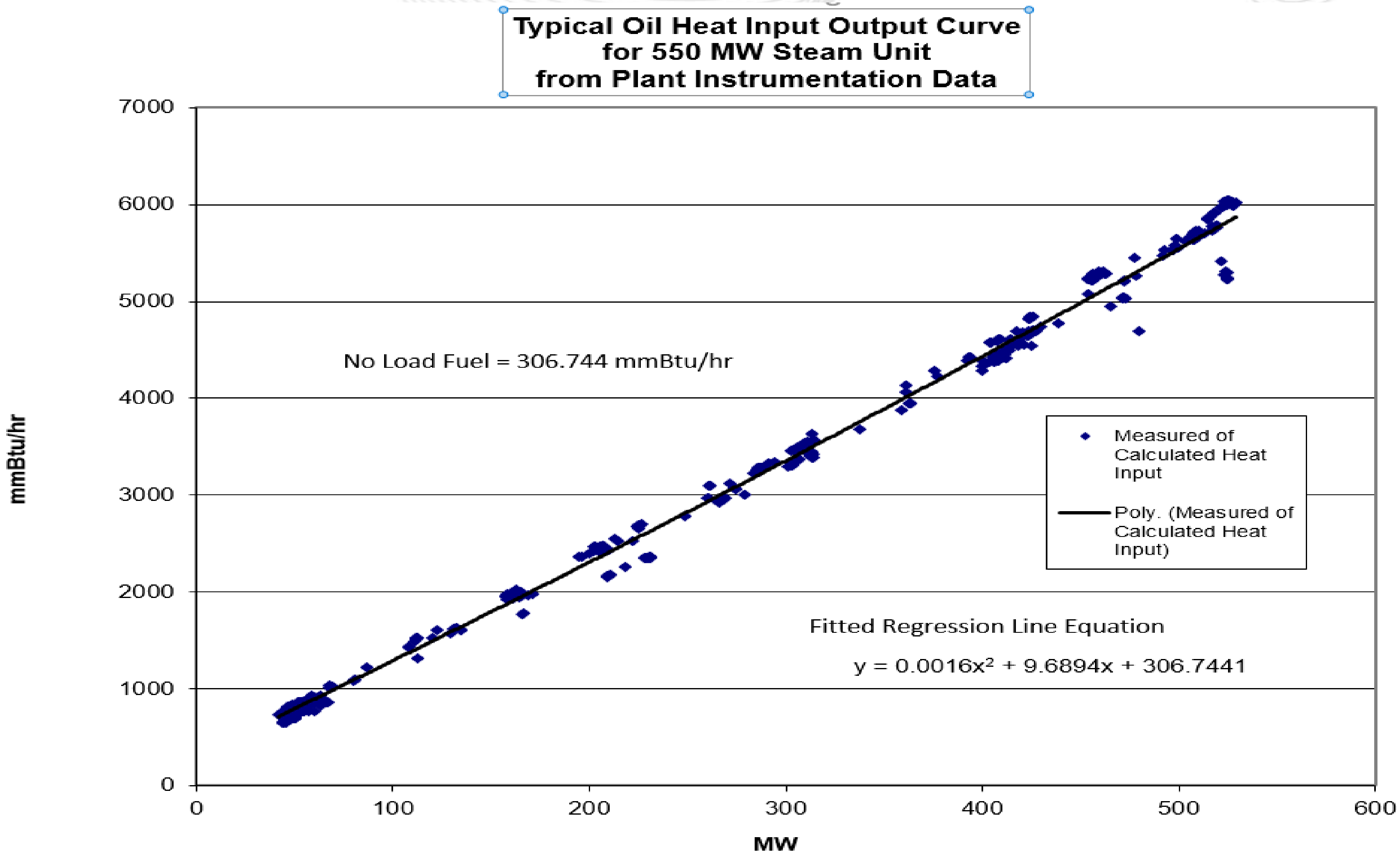
Creation of a No-Load & Incremental Energy Offer

- Data needed to create a No-Load and Incremental Energy Offer
  - Fuel Price (methodology in Fuel Cost policy)
  - Heat Input or Heat Rate Curve
  - Performance Factor
  - Maintenance Adder
  - Operating Cost Adder
  - Emissions Adders
- The bottom 5 items above are values Market Sellers input into MIRA

- Heat Input Curves are created from:
  - Normal operations data using plant instrumentation
    - Only steady state operation data should be used
  - Performance Test
  - OEM supplied design heat balances

- EXCEL or other data analysis tools used to determine A, B, C, coefficients for polynomial heat input equation
  - Heat Input = $A + B*x + C*x^{2} + \ldots$
    - Where x = MWh

Heat Input from Plant Data



Heat Input Curve for "Steam Unit 1"

- Heat Input Curve Coefficients
  - A = 306.7441
  - B = 9.6894
  - C = 0.0016

- Heat Input Curve
  - $\text{Heat Input} = 306.7441 + 9.6894*(\text{MWh}) + 0.0016*(\text{MWh})^2$

- Heat Input Curves are submitted to PJM and the IMM by MIRA's Cost Offer Assumption's Module (COA)
  - X^0 = A, X^1 = B, X^2 = C, and X^3 = D

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		Fuel 1	NG		🗑
		X^1		Fuel 2	[Select One]		
		X^2		Fuel 3	[Select One]		
		X^3					
100.1	200.0	X^0		Fuel 1	NG		🗑
		X^1		Fuel 2	[Select One]		
		X^2		Fuel 3	[Select One]		
		X^3					

- Input Variable for the Example
  - Total Fuel related Cost = $14.00/MMBtu
  - Performance Factor (PF) = 1.02
  - Maintenance and Operating Cost adders (VOM) = $0.15/MMBtu
  - Emissions adders = $0

Calculation of No-Load Cost

- No-Load Fuel is the total fuel to sustain zero net output MW at synchronous generator speed.

  using heat input = 306.7441 + 9.6894*(MWh) + 0.0016*$(MWh)^2$

  at 0 MWh = 306.7441 + 9.6894*(0) + 0.0016*$(0)^2$ (MMBtu/hour)

  No-Load Heat = 306.7441 MMBtu/hour

- No-Load Cost is the hourly cost required to create the starting point of a monotonically increasing incremental offer curve for a generating unit.

  No-Load Cost = No-Load Fuel * PF * (TFRC + VOM) ($/hour)

  = 306.7441 * 1.02 * (14.0 +0.15) ($/hour)

  No-Load Cost = $4,427.24 per hour

Incremental Energy Offer Calculation

- Two ways to calculate incremental energy offers
  - Block Offers
    - Block difference in Total Operating Cost
  - Slope Offers
    - Incremental Heat Rate Curve

- Calculate Total Operating Costs using total fuel related cost equation from M15 Section 2.3.3

$$TotalFuelRelatedCosts =$$

$$FuelCosts + FuelRelatedCosts + SO_2 AllowanceCost + CO_2 AllowanceCost + NO_x AllowanceCost + MaintenanceAdder$$

- Simplifies to:

Total Operating Cost ($/hr) = Heat Input * PF * (Fuel Cost + VOM)

= Heat Input * 1.02 * (14.00 + 0.15)

Steam Unit 1 Operating Cost

Total Operating Cost (50 MWh) = Heat Input(50 MWh) * PF * (Fuel Cost + VOM) ($/hour)
= 795.12 * 1.02 * (14.00 + 0.15)
= 11,476 $/hour

Output (MWh)	Heat Input (mmBtu/hr)	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

Block Load Offers

Incremental Cost (160 MWh) =

[Total Operating Cost (160 MWh) – Total Operating Cost (50 MWh)]/ [160 MWh - 50 MWh] ($/MWh)

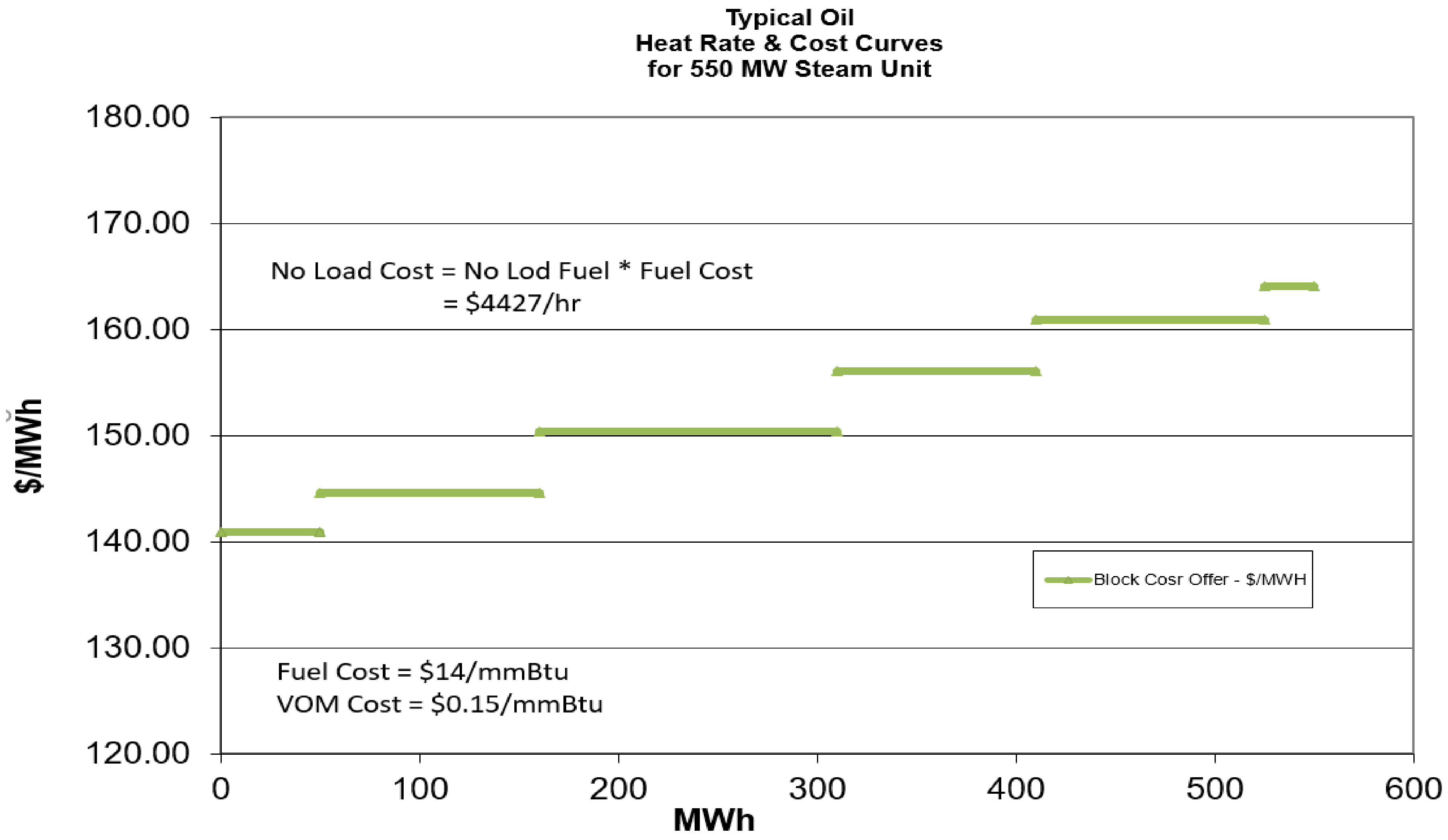
= [27,381 – 11,476] / [160 – 50]

= $144.59 per MWh

Output (MWh)	Incremental Offer ($/MWh)
50	140.98*
160	144.59
310	150.46
410	156.10
525	160.95
550	164.11

* When calculating the first incremental the No-Load Cost is used for Total Operating Cost at MWh (0)

Market Gateway Block Load Offer



- Slope Offers are calculated using the incremental heat rate equation which is the derivative of the Heat Input equation
  - Heat Input = 306.7441 + 9.6894*(MWh) + 0.0016*$(MWh)^2$
  - Incremental Heat Rate (IHR) = 9.6894 + (2 * 0.0016*(MWh))

- Including Fuel and VOM Cost
  - Incremental Offer ($/MWh) = IHR * PF * (Fuel Cost + VOM)

Slope Offers

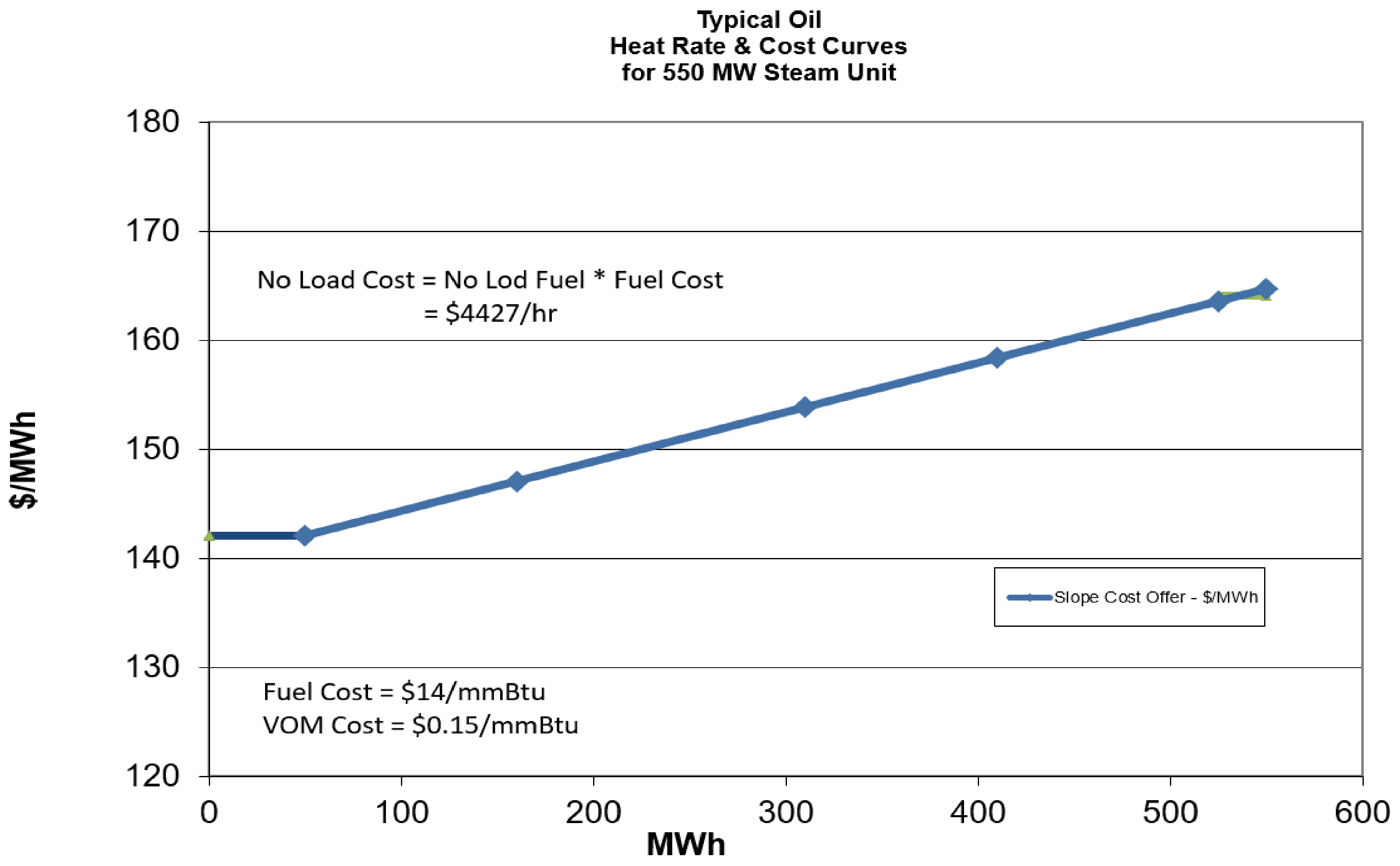
Incremental Cost (50 MWh) = IHR * PF * (Fuel Cost + VOM)

= [9.6894 + (2 * 0.0016*50)] * 1.02 * (14.00 + 0.15)

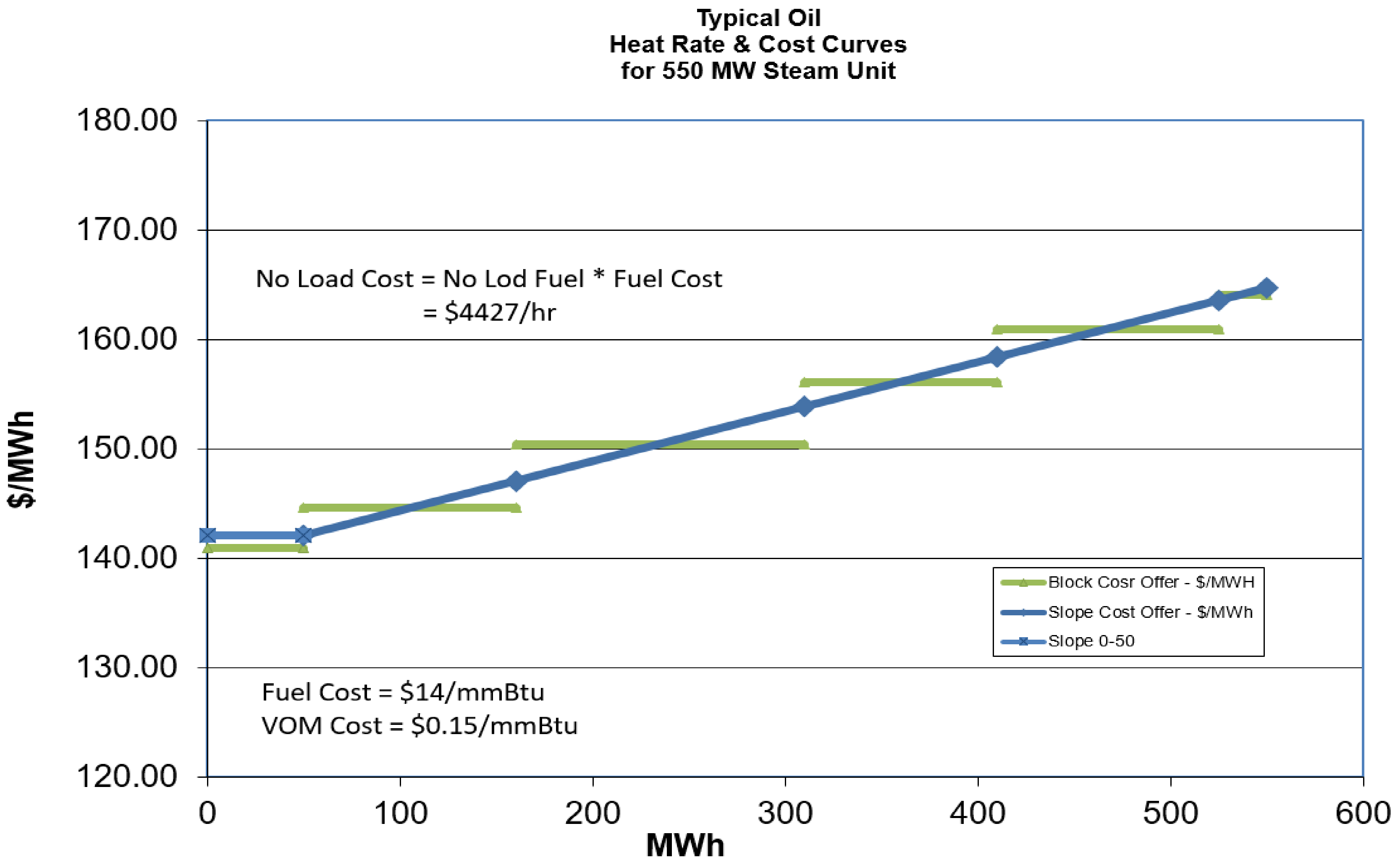
= $142.10 per MWh

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

Market Gateway Slope Offer



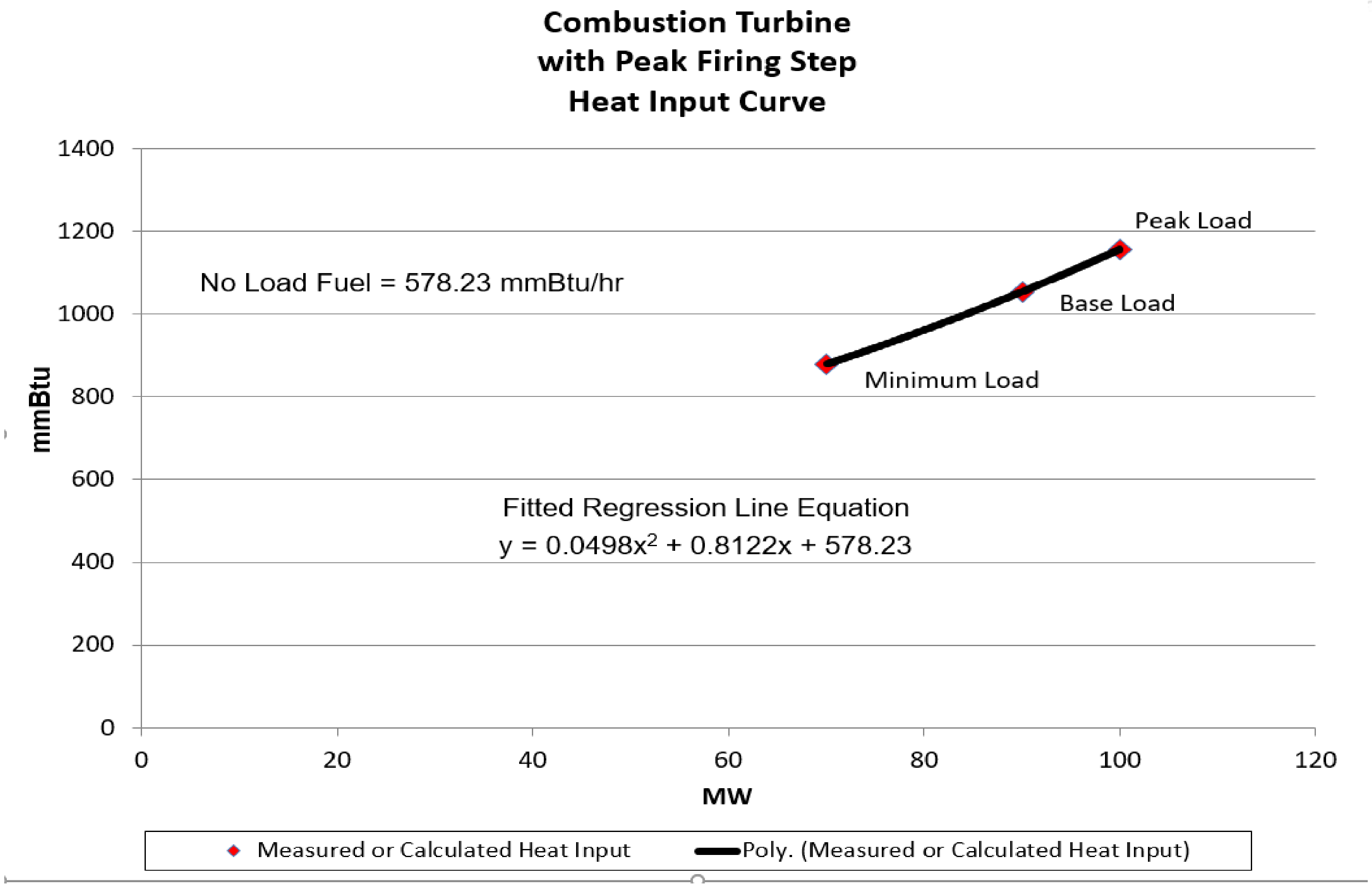
Comparison of Slope and Block Offers



Simple Cycle Combustion Turbine Example

- 100 MW simple cycle combustion turbine
  - With fuel cost = $4 /MMBtu
  - performance factor = 1.02
  - 70 MW minimum load
  - Maintenance Adder of $75 / equivalent service hour (ESH)
  - 10 MW peak firing step with a maintenance factor of 4 for peak firing step

Simple Cycle CT Heat Input Curve



Heat Input Curve for “CT Unit 2”

- Heat Input Curve
  - Heat Input = 578.23 + 0.8122*(MWh) + 0.0498*(MWh)^2

- Heat Input Curve Coefficients
  - A = 578.23
  - B = 0.8122
  - C = 0.0498

- No-Load Heat = 578.23 MMBtu/hr

- Calculate No-Load Cost

  No-Load Cost = [No-Load Fuel * PF * TFRC] + VOM** ($/hour)

  = [578.23 * 1.02 * 4.0] + 0 ($/hr)

  No-Load Cost = $2359.18 per hour

- Calculate Total Operating Cost
- Total Operating Cost ($/hour) = [Heat Input * PF * Fuel Cost] + [Maintenance Factor# * VOM**]

  = [Heat Input * 1.02 * 4.00] + [MF * VOM]

** VOM in $/ESH can be added to either No-Load or first incremental but not both

Maintenance Factor is equal to 1 for base load and below and equal to (4-1) for peak firing step

CT Unit 2 Operating Cost

Total Operating Cost (70 MWh) = (Heat Input(70 MW) * PF * Fuel Cost) + VOM ($/hr)
= (879.02 * 1.02 * 4.00) + 75
= 3,662 $/hour

Output (MWh)	Heat Input (mmBtu/hr)	Operating Cost ($/hr)
70	879.02	3,662
90	1054.57	4,378
100	1157.28	5,022

Incremental Cost (90 MWh) =

[Total Operating Cost (90 MWh) – Total Operating Cost (70 MWh)]/ [90 MWh - 70 MWh] ($/MWh)

= [4,378 – 3,662] / [90 – 70]

= $35.82 per MWh

Output (MWh)	Incremental Offer ($/MWh)
70	18.61*
90	35.82
100	64.42

* When calculating the first incremental the No-Load Cost is used for Total Operating Cost at MWh (0)

- Slope Offers are calculated using the incremental heat rate equation which is the derivative of the Heat Input equation
  - Heat Input = 578.23 + 0.8122*(MWh) + 0.0498*(MWh)^2
  - Incremental Heat Rate (IHR) = 0.8122 + (2 * 0.0498*MWh)

- Including Fuel and VOM Cost
  - Incremental Offer ($/MWh) = [IHR * PF * Fuel Cost] + [(Maintenance Factor# * VOM)/ (MWh(1) – MWh(0)]

Maintenance Factor is equal to 1 for base load and below and equal to (4-1) for peak firing step

Incremental Cost (100 MWh) =

[Incremental Offer ($/MWh) = [IHR * PF * Fuel Cost] + [(Maintenance Factor# * VOM)/ (MWh(1) – MWh(0)] $/MWh

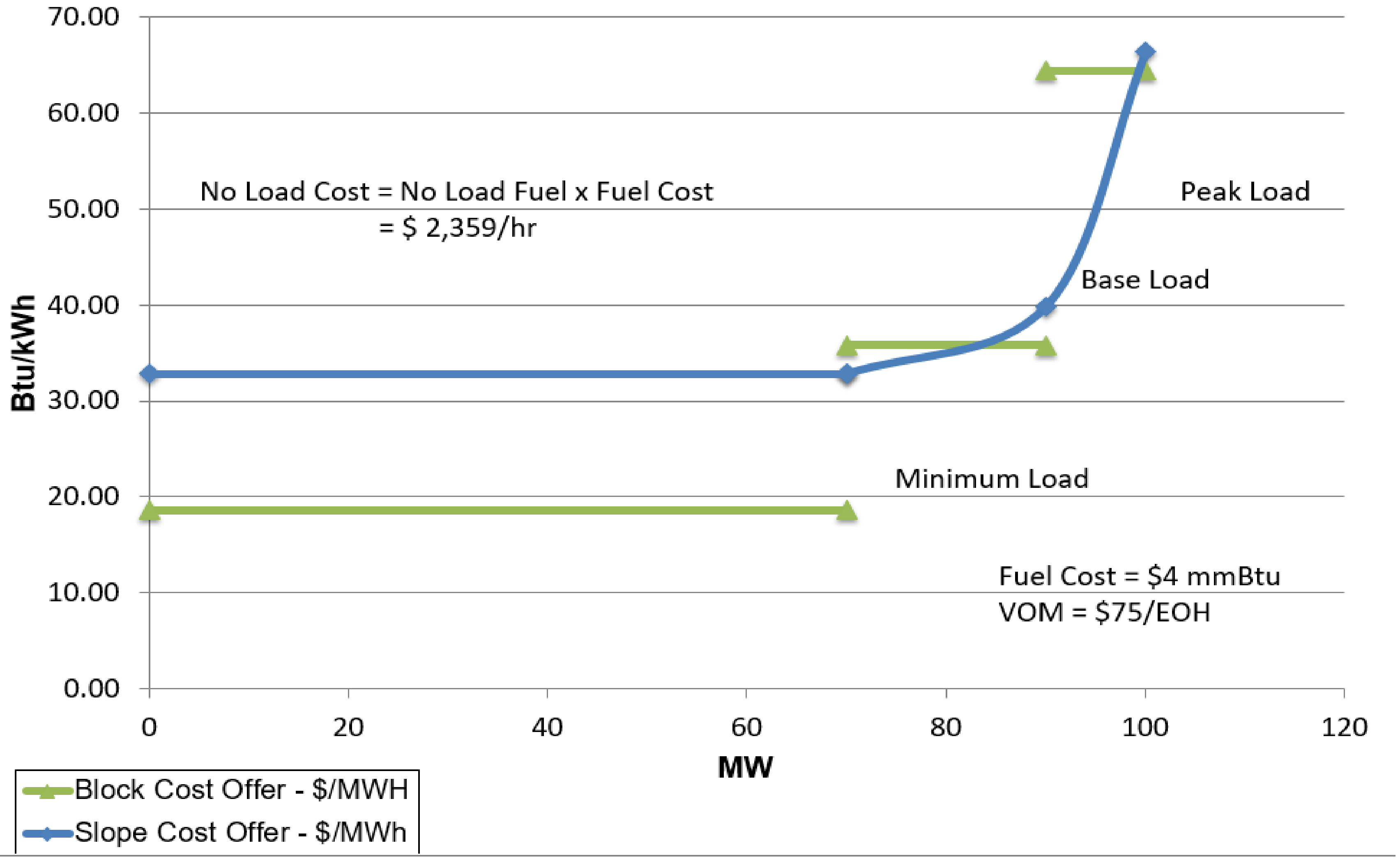
= [(0.8122 + (2 * 0.0498 * 100)) * 1.02 * 4] + [((4 – 1) * 75) / (100 – 90)]

= $66.45 per MWh

Output (MWh)	Incremental Offer ($/MWh)
70	32.83
90	39.89
100	66.45

Maintenance Factor is equal to 1 for base load and below and equal to (4-1) for peak firing step

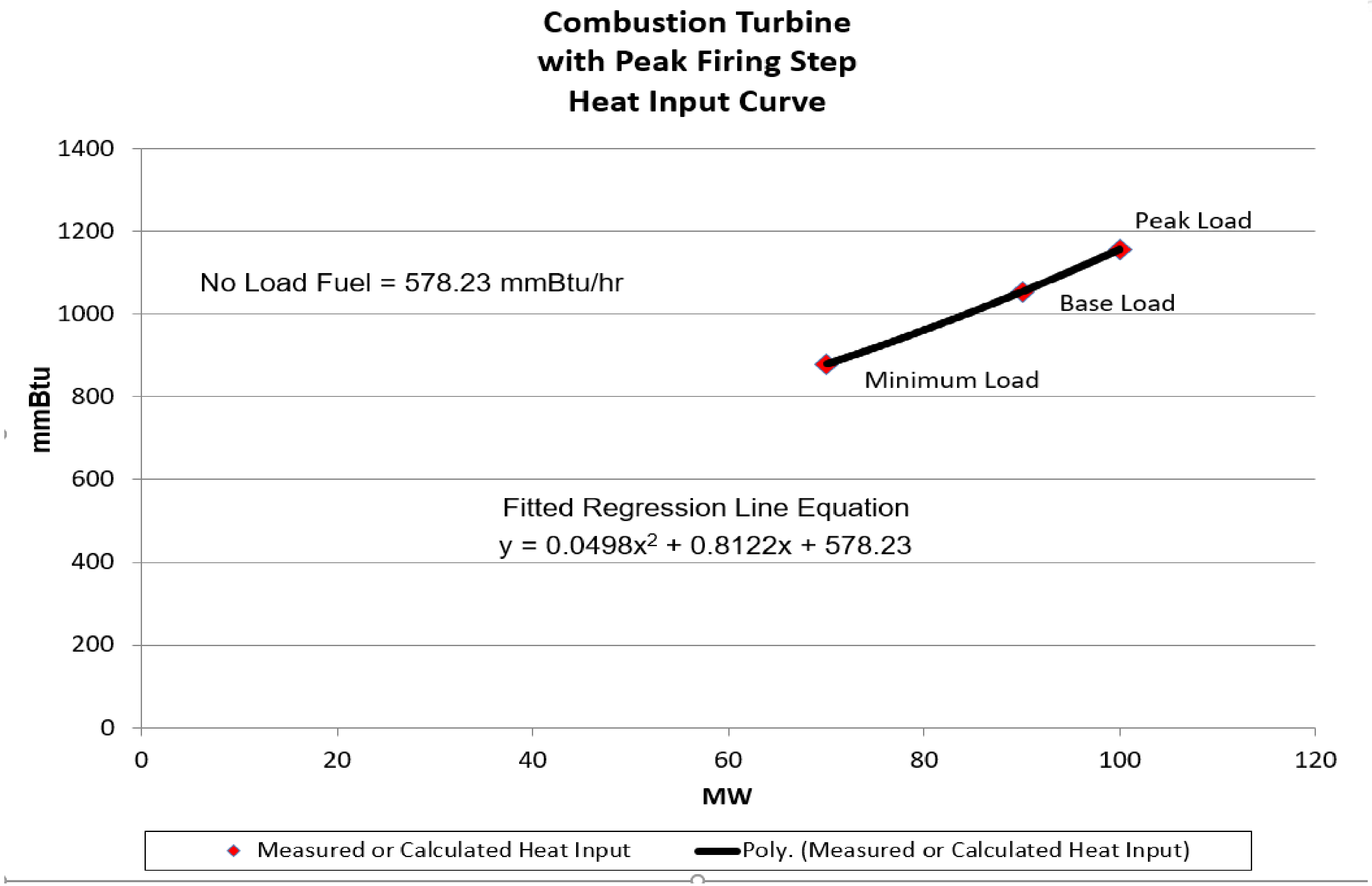
CT Block & Slope Offer



Average Heat Rate Example

- 90 MW simple cycle combustion turbine
  - With fuel cost = $4/MMBtu
  - performance factor = 1.02
  - Offered as one block load
  - Maintenance Adder of $75 / hour

Using Simple Cycle CT Heat Input Curve



Average Heat Rate for “CT Unit 3”

- Calculate Average Heat Rate at 90 MWh

  Average HR = Heat Input (@90 MWh) / 90MWh (MMBtu/MWh)

  $= [578.23 + 0.8122*(90) + 0.0498*(90)^2] / 90$

  = 11.717 MMBtu/MWh

Average Heat Rate for “CT Unit 3”

- Average Heat Rate = 11.717 MMBtu/MWh

- Heat Input Curve Coefficients entered into MIRA
  - A = 0
  - B = 11.717
  - C = 0

- No-Load Heat = 0 MMBtu/hr

- Calculate No-Load Cost

  No-Load Cost = [No-Load Fuel * PF * TFRC] + VOM** ($/hour)

  = [0 * 1.02 * 4.0] + 0 ($/hr)

  No-Load Cost = $0 per hour

- Calculate Total Operating Cost
- Total Operating Cost ($/hour) = [Heat Input * PF * Fuel Cost] + VOM**

  = [Heat Input * 1.02 * 4.00] + VOM

** VOM in $/hour can be added to either No-Load or first incremental but not both

CT Unit 3 Operating Cost

Heat Input (90 MWh) = 0 + (11.718 * 90) + (0 * 90^2) (MMBtu/hr)
= 1054.57 MMBtu/hr

Total Operating Cost (90 MWh) = (Heat Input(90 MW) * PF * Fuel Cost) + VOM ($/hr)
= (1054.57 * 1.02 * 4.00) + 75
= 4,378 $/hour

Output (MWh)	Heat Input (mmBtu/hr)	Operating Cost ($/hr)
90	1054.57	4,378

Average Heat Rate CT Block Load Offers

Incremental Cost (90 MWh) =

[Total Operating Cost (90 MWh) – Total Operating Cost (0 MWh)]/ [90 MWh - 0 MWh] ($/MWh)

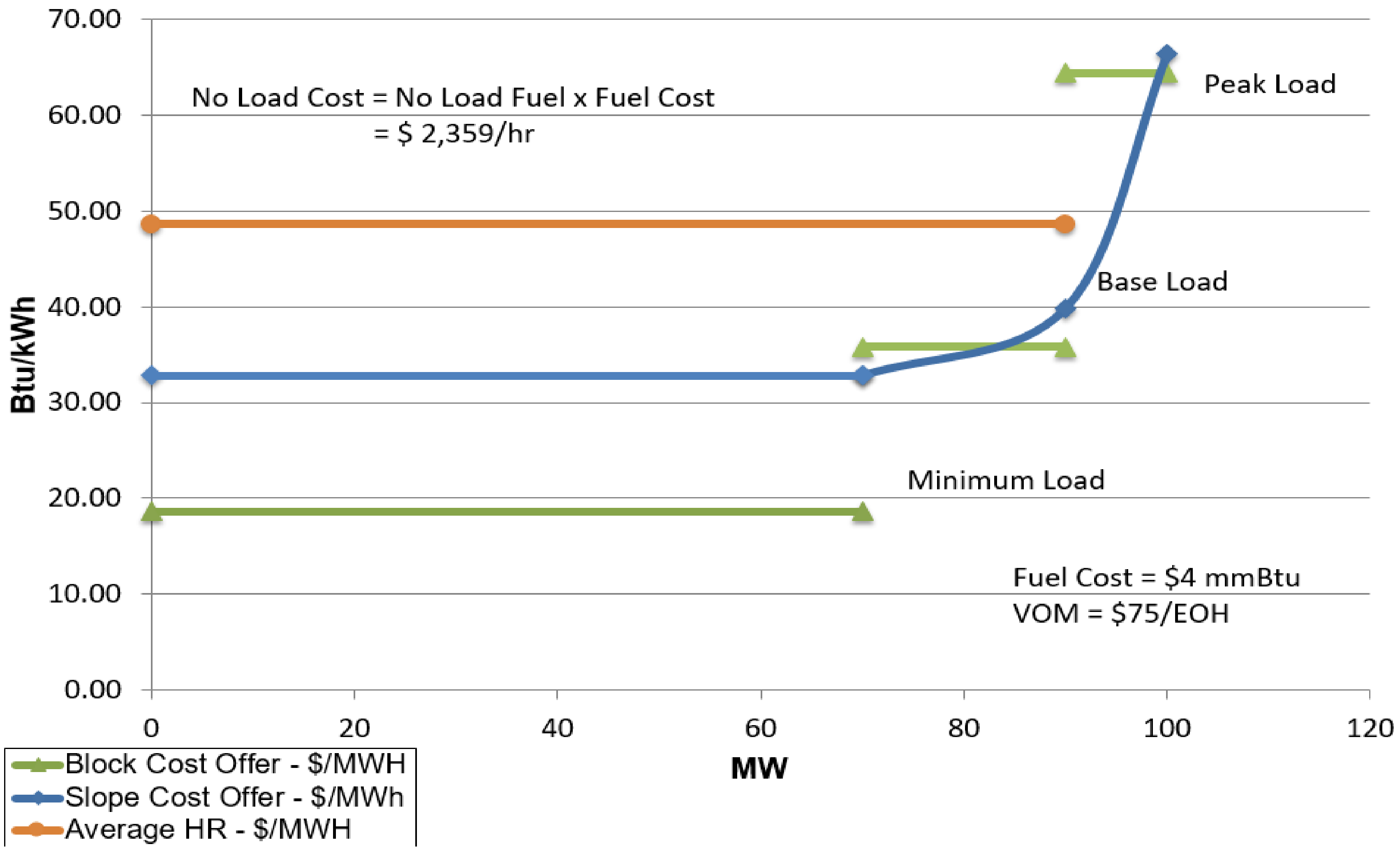
= [4,378 – 0] / [90 – 0]

= $48.64 per MWh

Output (MWh)	Incremental Offer ($/MWh)
90	48.64*

* When calculating the first incremental the No-Load Cost is used for Total Operating Cost at MWh (0)

CT Block, Slope, & Average HR Offer

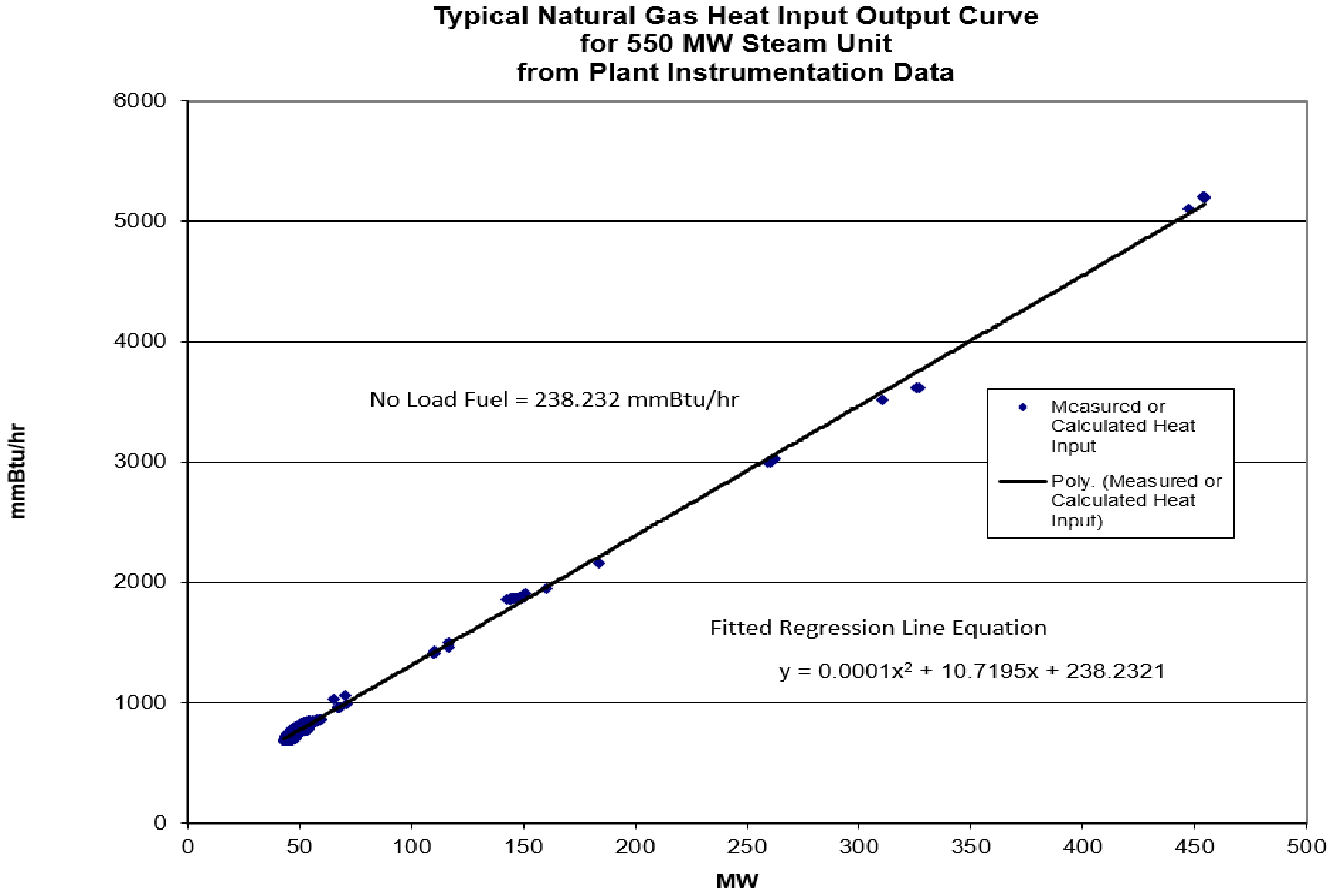


- Manual 15 Attachment H Section B.4 provides a similar example for a 2x1 combined cycle with duct firing

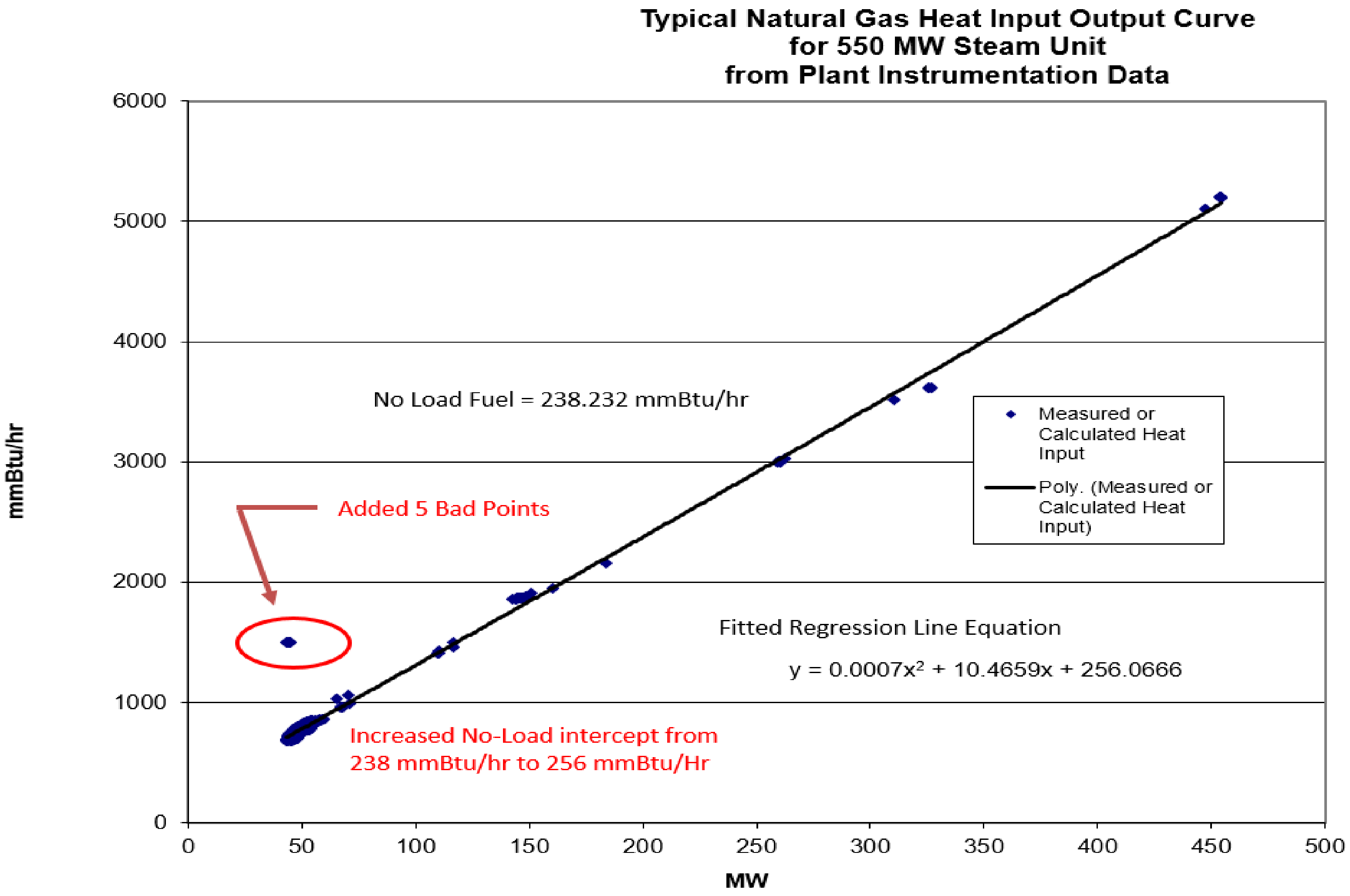
Importance of Good Data

- Cost Offers always start with a heat input curve
- When developing heat input curves
  - Try to maximize the number of data points
  - Use steady state operation data
  - Remove obvious bad data

Heat Input Curve with Limited Data



Example of Impact of Bad Data



Contact

CDS Chair :
Nicole Scott ,
Nicole.Scott@pjm.com

CDS Secretary:
Heather Reiter,
Heather.Reiter@pjm.com

Presenter/SME:
Thomas Hauske,
Thomas.Hauske@pjm.com

Member Hotline

(610) 666 – 8980

(866) 400 – 8980

custsvc@pjm.com