GRU℠

More than Energy

Heat Rate Presentation

Utility Advisory Board Workshop

April 24, 2018

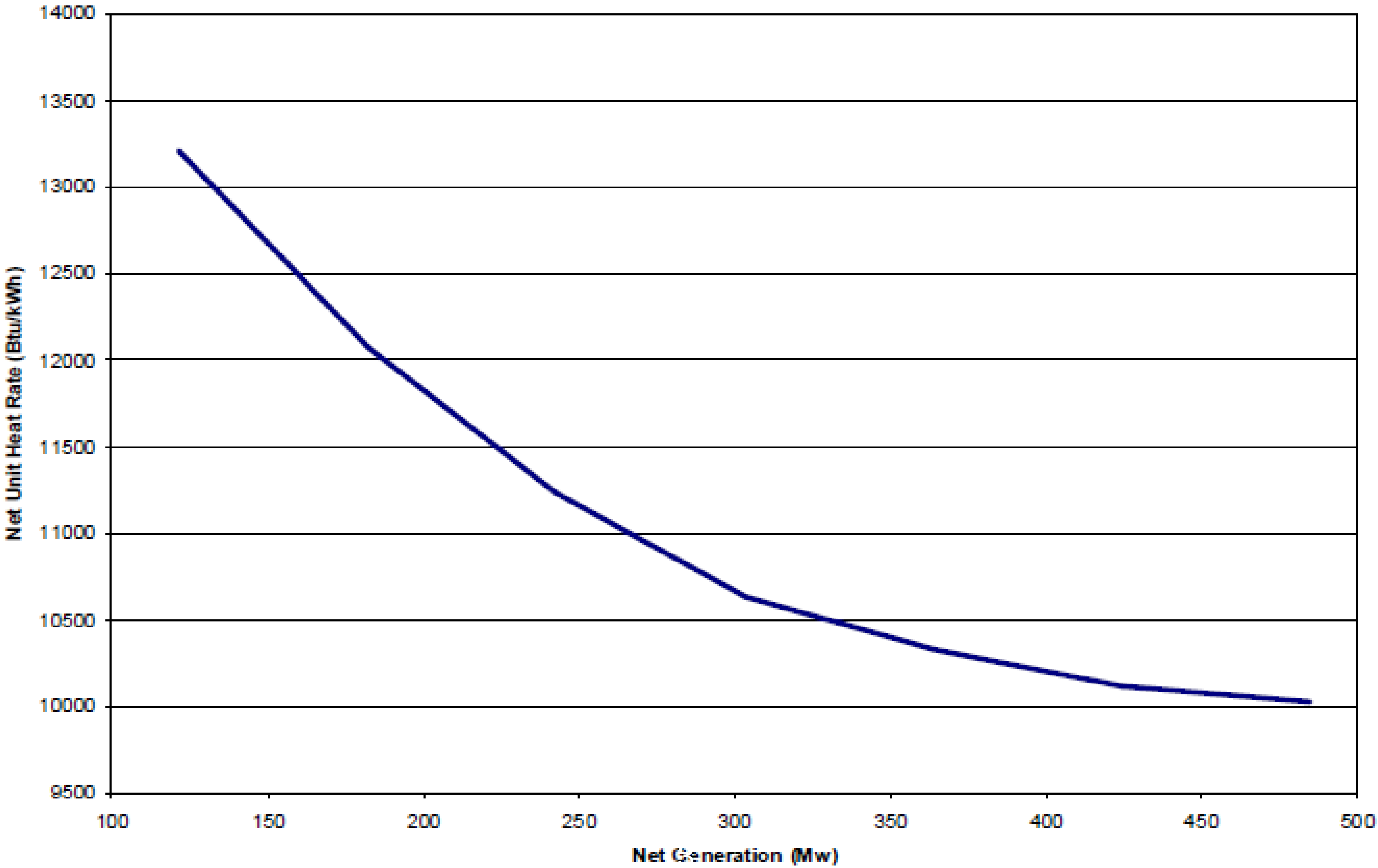
Heat Rate

The common measure of system efficiency in a power plant.

$$HeatRate(Btu/kWh) = \frac{Energy\ Input\,(Btu/hr)}{Power\ Output\,(kW)}$$

- Increasing heat rate – decreasing efficiency
- Decreasing heat rate – increasing efficiency

Typical Heat Rate Curve



Heat Rate Determination

- Net Unit Heat Rate
  - Measure of the combined performance of the turbine cycle, boiler cycle, and any other associated auxiliaries
- Energy Input
  - *Energy In Fuel = Fuel Flow(lbm/ hr)*FuelHeatingValue(Btu/ lbm)*
- *Net Unit Heat Rate:*

$$Net\ Heat\ Rate(Btu/kWh) = \frac{Fuel\ Flow(lbm/hr) * Fuel\ Heating\ Value(Btu/lbm)}{Net\ Power\ Output(kW)}$$

Why is Heat Rate Important?

- 70 - 80 % of our overall production cost is our fuel
- Aging plants are more susceptible to efficiency losses over time
  - Plants are generally designed for 30 to 40 year life
- Directly impacts expenses
- The bottom line is the heat rate(efficiency) integrated with the actual commodity pricing are key factors in determining the optimal economic dispatch of GRU generating units.

Power Plant Efficiency Objectives

- Boiler Combustion Side
  - Maximize heat transferred to the working fluid
  - Minimize heat losses from the system
    - Flue gas
    - Unburned carbon – complete combustion
    - Radiation
- Turbine Side / Balance of plant
  - Maximize thermal energy utilization
  - Minimize aux power usage
  - Minimize losses

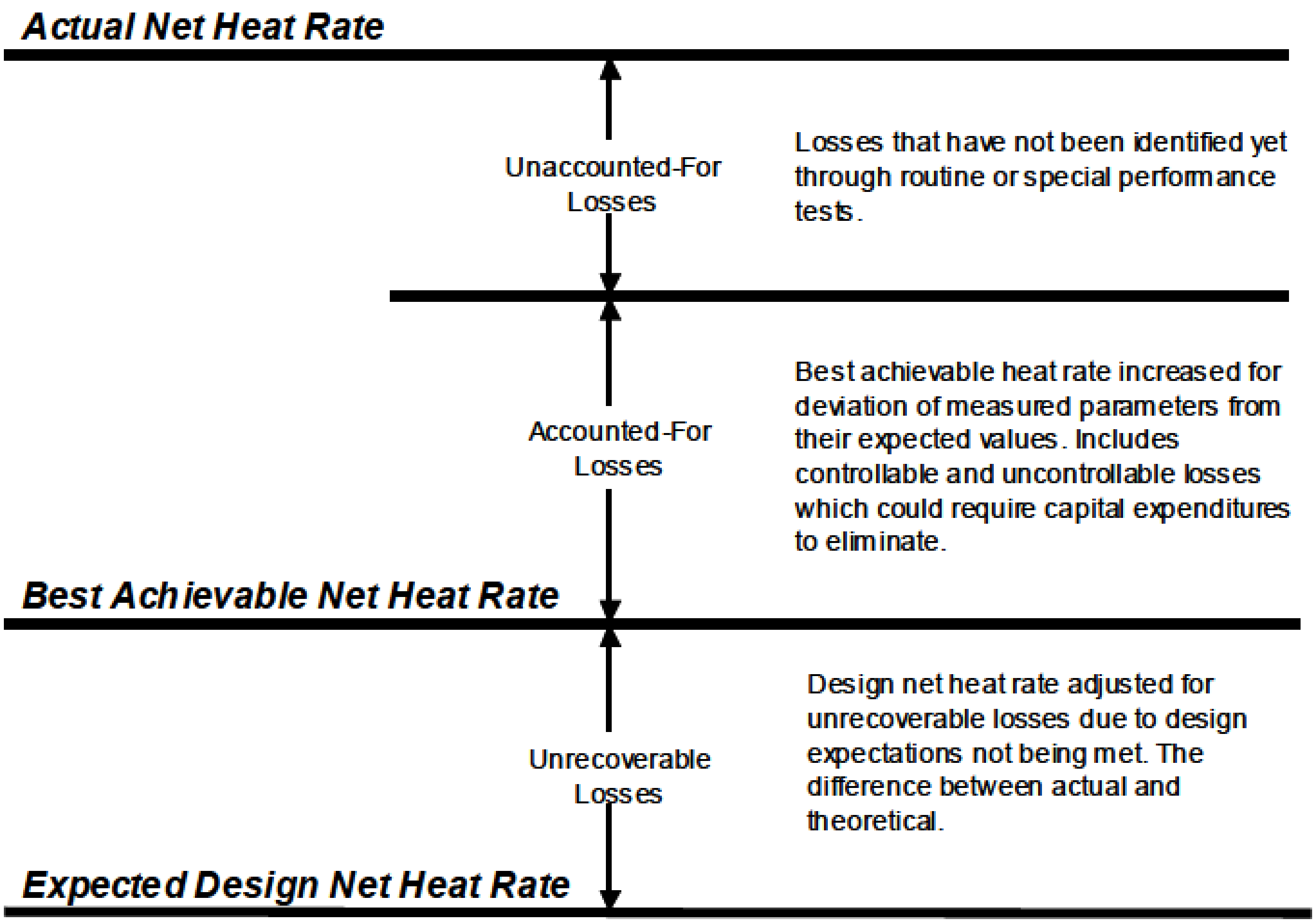
Boiler Efficiency

$$Boiler\ Efficiency = \frac{Btus\ Transferred\ To\ Working\ Fluid\ (water\ or\ steam)}{Btus\ Input\ As\ Fuel}$$

Or

$$Efficiency = \frac{Useful\ Energy\ Output}{Energy\ Input}$$

Definition of Standards for Heat Rate



Boiler Efficiency – Off Design Fuel

Fuel	Typical Energy Content (HHV)		Higher Heating Value (Btu/lb)	
No. 2 Fuel Oil	137,800	Btu/gal	18,596	Btu/lb
No. 6 Fuel Oil	150,500	Btu/gal	20,421	Btu/lb
Natural Gas	1,027	Btu/cu ft	22,810	Btu/lb
Performance Coal	12,700	Btu/lb	12,700	Btu/lb
Compliance Coal	12,500	Btu/lb	12,500	Btu/lb
Biomass[1]	5,000	Btu/lb	5,000	Btu/lb

1. Biomass HHV assumes that DHR is run at full load.

Heat Rate Curves

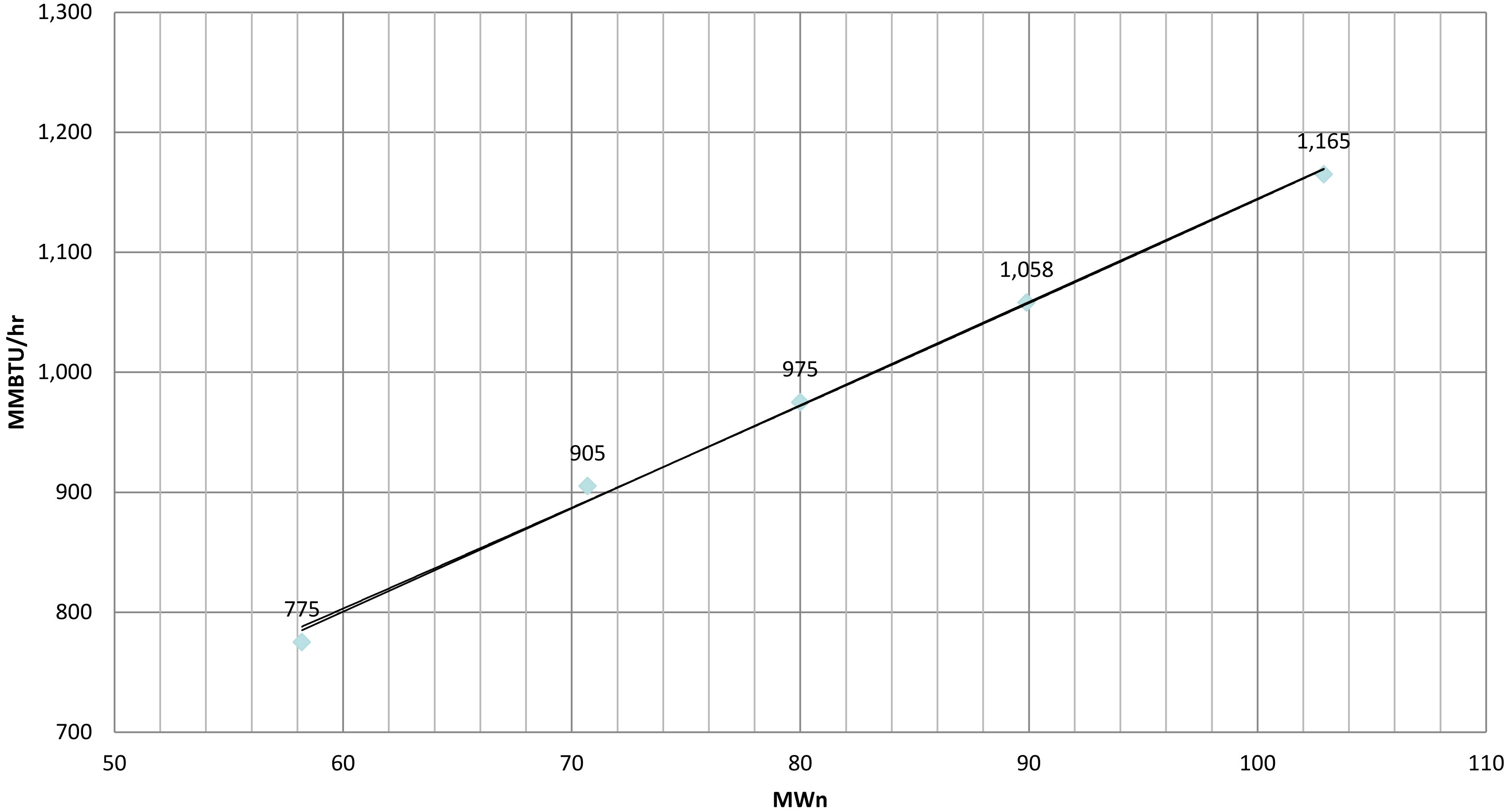
- Deerhaven Renewable
- Deerhaven Unit 2

2017 DHR HR DATA

MWn	Fuel Feed (lb/hr)	Heat Input (MMBTU/hr)	Average Heat Rate (MMBTU/MWn-h)
58.2	155,044	775	13.30
70.7	181,144	905	12.80
80.0	195,184	975	12.18
89.9	211,767	1,058	11.76
102.9	233,106	1,165	11.31

* Heating Value (BTU/lb)	4,996
* Density (lb/ft3)	23.15

2017 DHR Heat Input Curve



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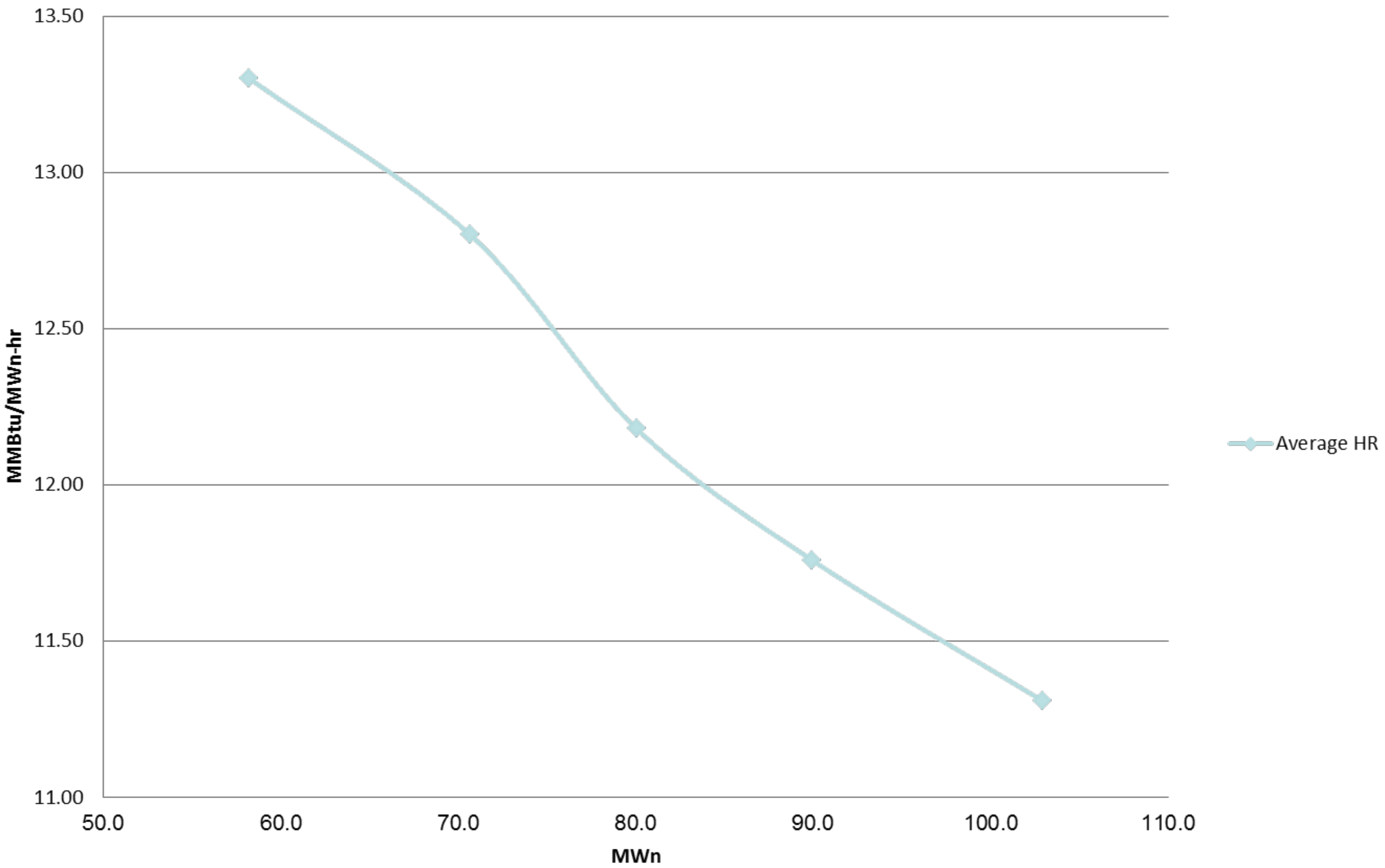
2017 DHR Average Heat Rate Curve



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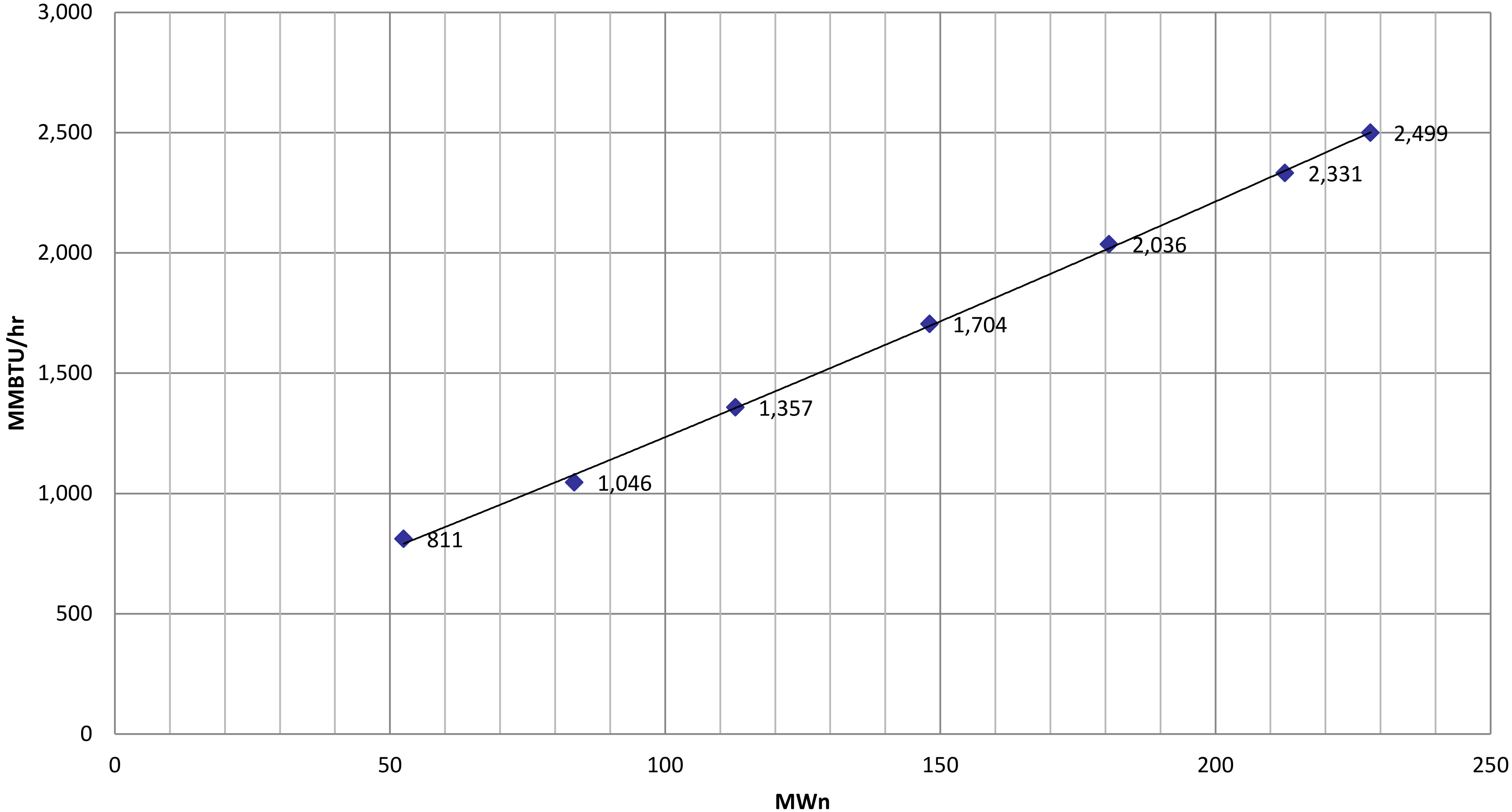
2017 DH2 HR DATA

MWn	Fuel Feed (lb/hr)	Heat Input (MMBTU/hr)	Average Heat Rate (MMBTU/MWn-h)
52.5	40,410	811	15.44
83.5	53,740	1,046	12.83
112.8	90,940	1,357	11.95
148.1	117,710	1,704	11.45
180.7	141,300	2,036	11.39
212.7	158,880	2,331	10.98
228.2	167,060	2,499	10.93

* Heating Value (BTU/lb) 12,966

2017 DH2 Heat Input Curve



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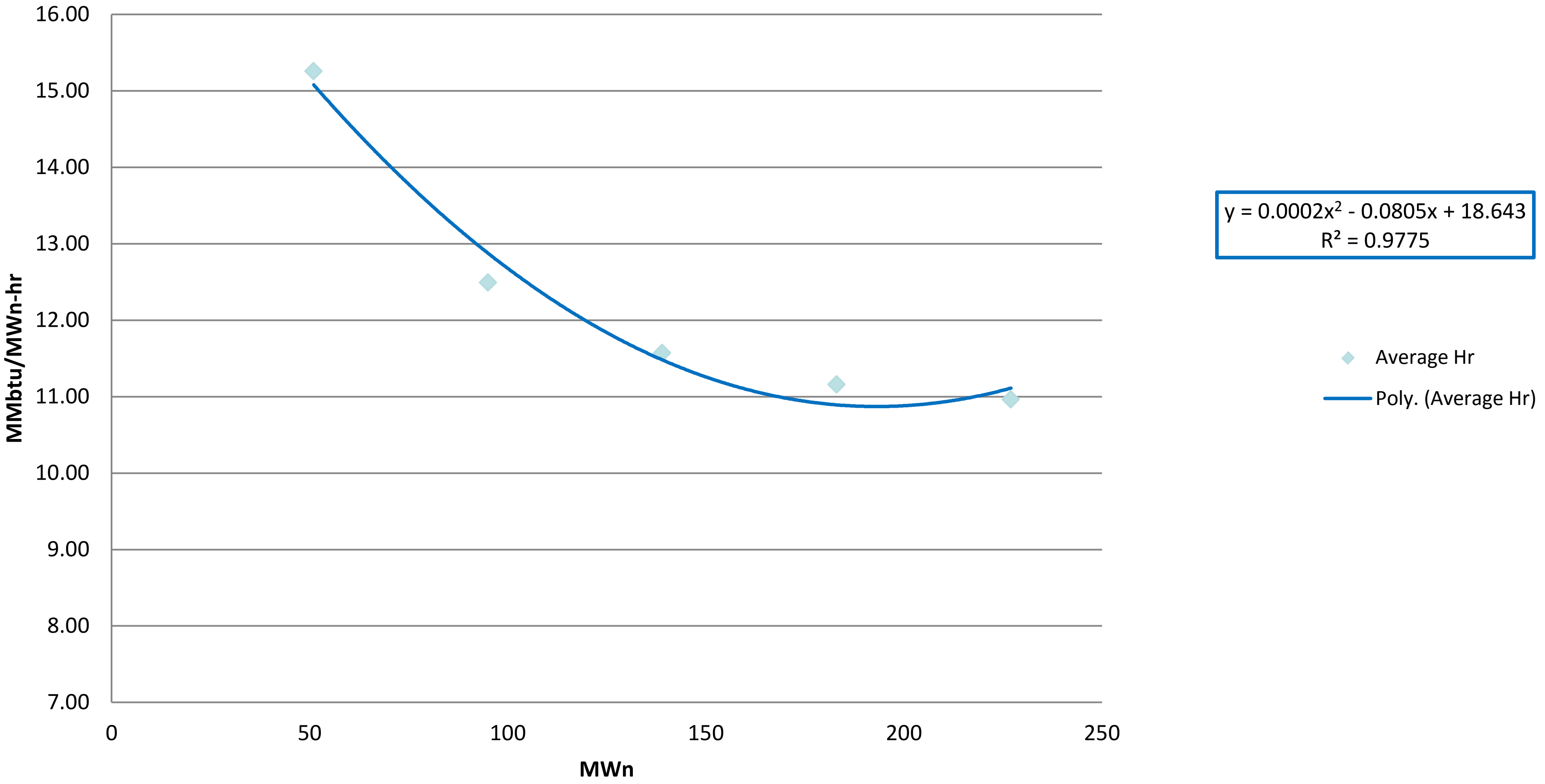
2017 DH2 Average Heat Rate Curve



Questions?